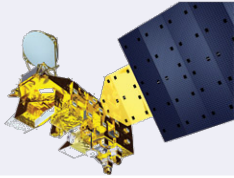

AIRS and CrIS calibration comparisons in cloudy scenes

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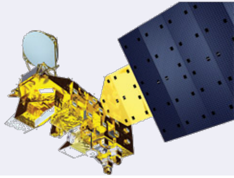
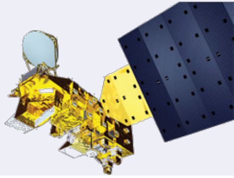
Outline



- AIRS/CrIS continuity
- Tropical SNO intro
- First comparison: CrIS by FOV number and sweep direction
- New tool: CrIS 2 AIRS spectral resampling
- Preliminary results: AIRS vs. CrIS
- Conclusions
- Future work
- Post-meeting extra



AIRS/CrIS continuity

- AIRS and CrIS are similarly capable hyperspectral IR sounders.
- AIRS has been in orbit since 2002; CrIS since 2012 and has been full-resolution since late 2014.
- We need to make a long-term climate record by merging these records.
  - Ohring et al 2005 sets the required level at 100 mK or better to resolve expected 100 mK/decade warming
  - Aumann's law: when you try to make comparisons below the 100 mK level everything turns to mush.
- So how similar are the data really?
- Tropical SNOs provide a comparison data set to address these issues.
  - Hopefully differences can be addressed by the AIRS and CrIS instrument teams

Tropical SNOs

For TSNO (tropical SNO) we collect spectra where:

- FOV centers are within 8 km
- Observations are within 10 minutes
- Both instruments observe within +/- 3 FOR (3 AMSU FOVs; 9.9 degrees) of nadir
- Latitude is within 30 degrees of the equator

For AIRS we use Level-1C to remove gaps and blemishes.

For CrIS we use UMBC CCAST Full Resolution for the latest and greatest calibration and a better match to AIRS sampling.

For a general intro to TSNO see my presentation from April 2015.

Data Set

- Data are collected for ~10 matching days in each of 3 months: January, May, and June 2015.
  – Each matching day has ~30,000 SNOs over ~10 hours or ~6 orbits
  – ~8,000 if we restrict comparisons to nighttime ocean

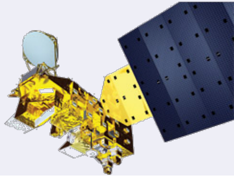
- Depending on the quantity we display daily or monthly statistics.

- The difference in 900 cm^{-1} brightness temperature, BT900, has a standard deviation of ~3 K.
  – We discard outliers over 5 K (~10% of cases), leaving a std dev ~1.5 K.

- Data shown here are all near-nadir tropical night ocean.

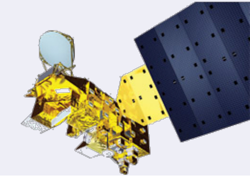
- Differences quoted in Kelvins are actually radiance differences converted at an effective scene temperature of 250 K.

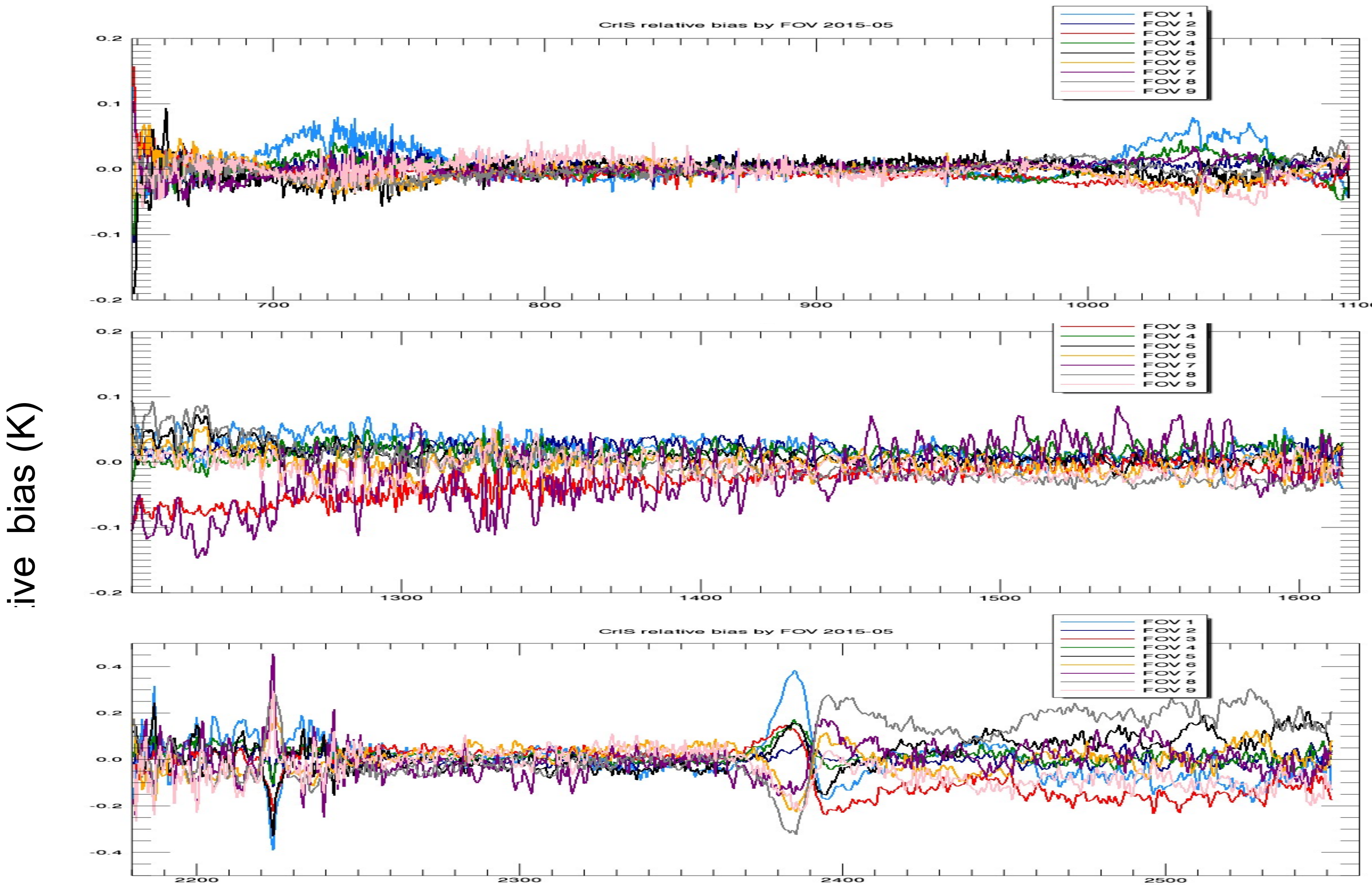
Using TSNOs to analyze CrIS



- The simplest application of TSNOs is to compare different subsets of data from one instrument.
  - But this is complicated as seen in the final part of this talk.
- The second instrument is used only to compensate for scene differences:
  - (CrIS FOV #1 – AIRS near CrIS FOV #1) - (CrIS FOV #2 – AIRS near CrIS FOV #2) gives a better estimate of differences between CrIS FOV #1 and CrIS FOV #2 than a simple average
  - AIRS instrument anomalies and artifacts of AIR/CrIS channel mismatch cancel out
  - This will eventually also be applied to AIRS.
- Next slides show the 9 CrIS FOVs relative to CrIS mean

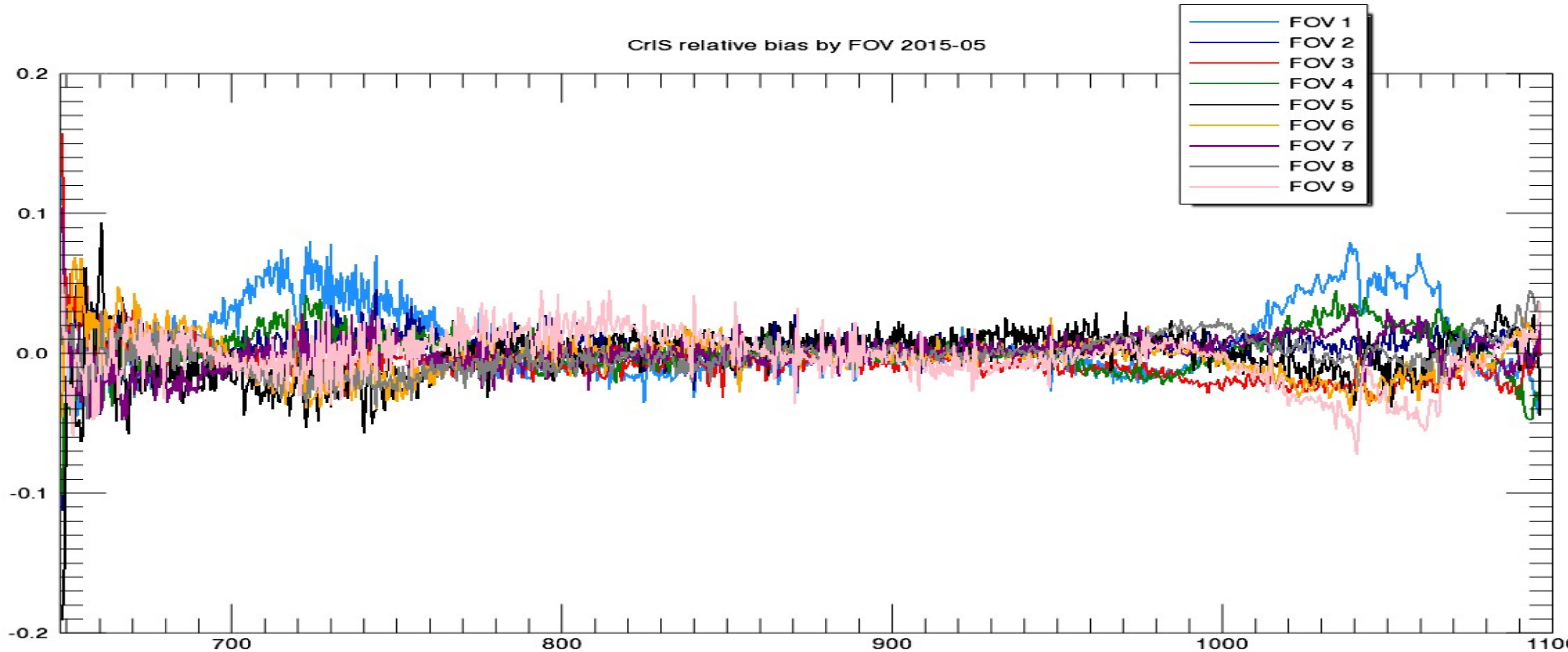
CrIS By FOV




CrIS relative bias by FOV 2015-05
FOV 1
FOV 2
FOV 3
FOV 4
FOV 5
FOV 6
FOV 7
FOV 8
FOV 9
0.2
0.1
0.0
-0.1
-0.2
700
800
900
1000
1100
1300
1400
1500
1600
ive bias (K)
CrIS relative bias by FOV 2015-05
0.4
0.2
0.0
-0.2
-0.4
2200
2300
2400
2500

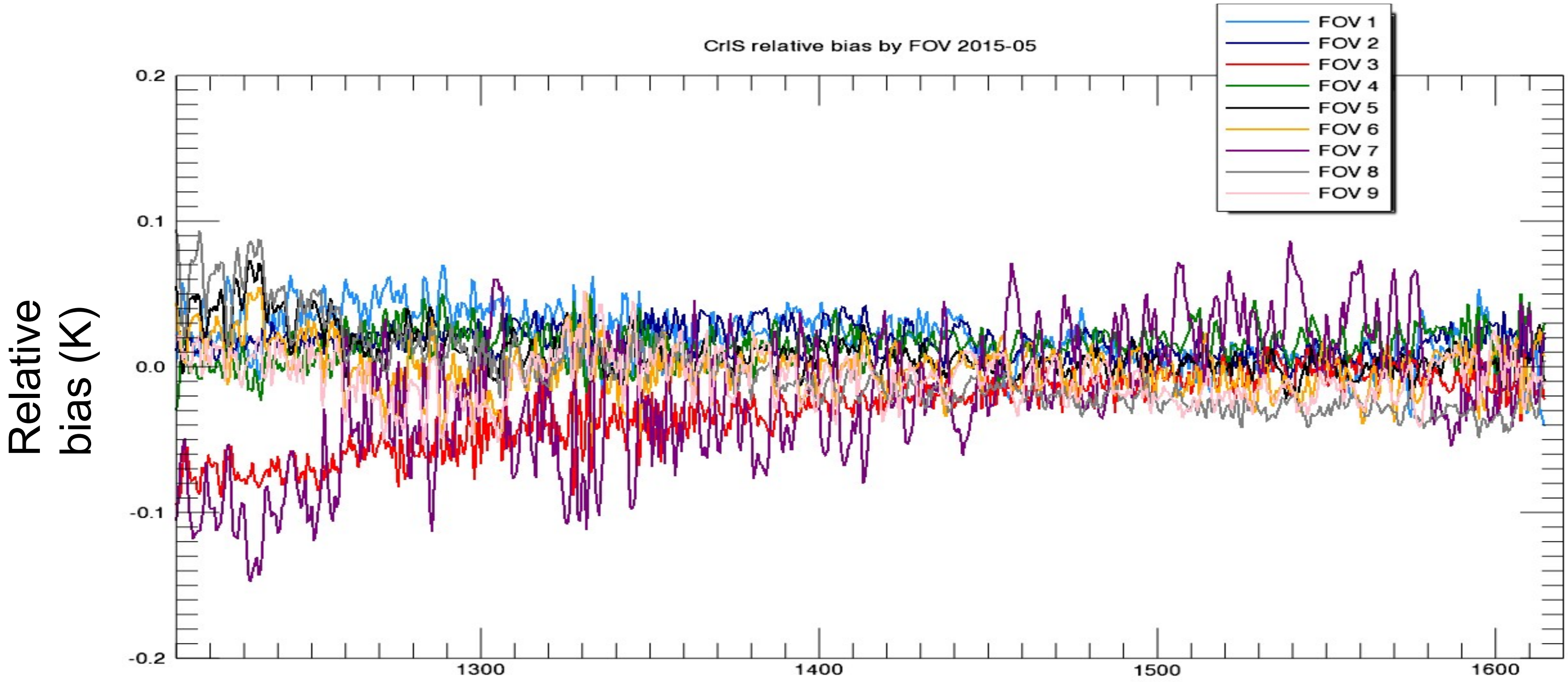
CrIS LW by FOV

Relative bias (K)



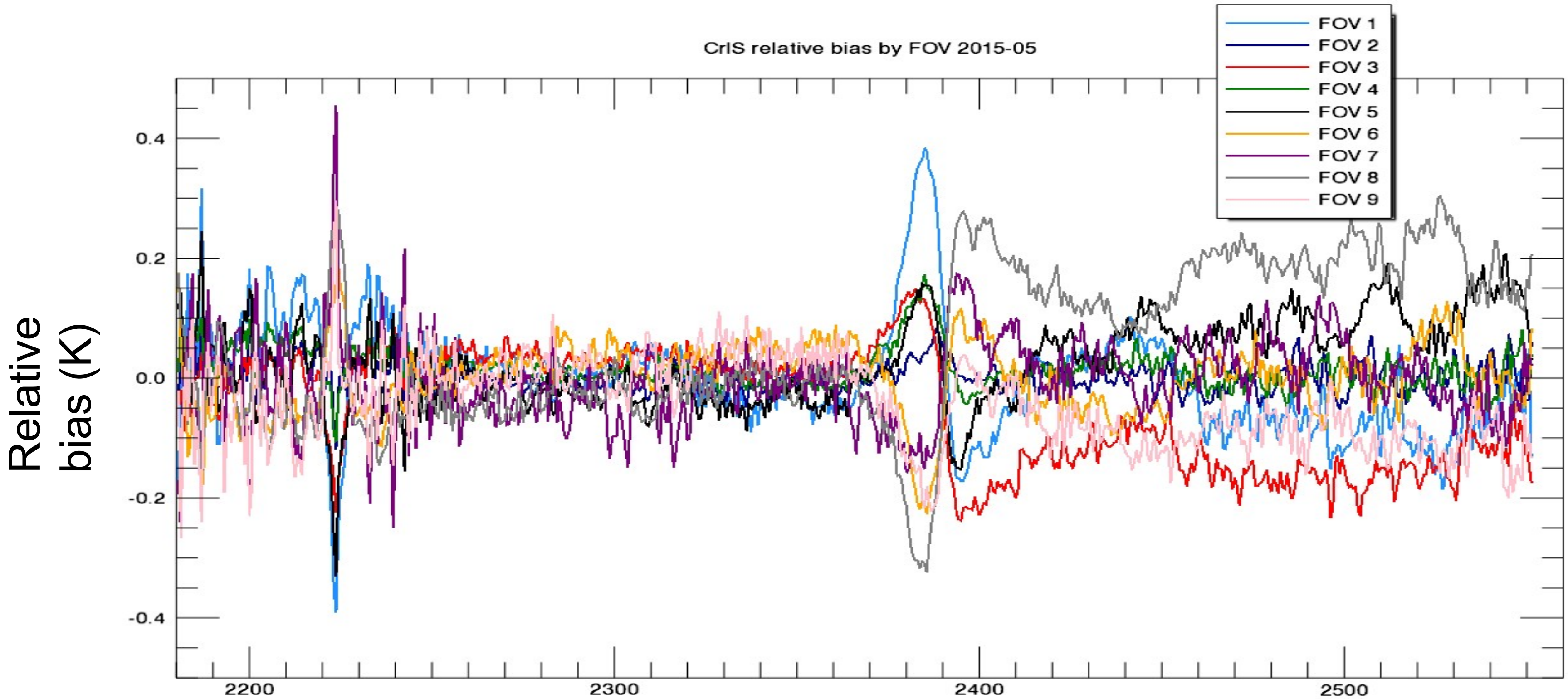
- In the longwave we see two regions of divergence among the FOVs
  - ~720 cm^{-1}
  - ~1040 cm^{-1} (ozone band)
- FOV is warmest in both cases
- Differences are less than but almost 100 mK
  - Over 100 mK if sweep direction is included

CrIS MW By FOV



- In the midwave FOV 7 (purple) has known nonlinearity problems, which probably explain the “structure”.
  - A newer version of CCAST with nonlinearity update will be evaluated soon.
- FOV 7 (purple) and FOV 3 (red) have a slope across the band
- Both effects are less than 100 mK but significant.

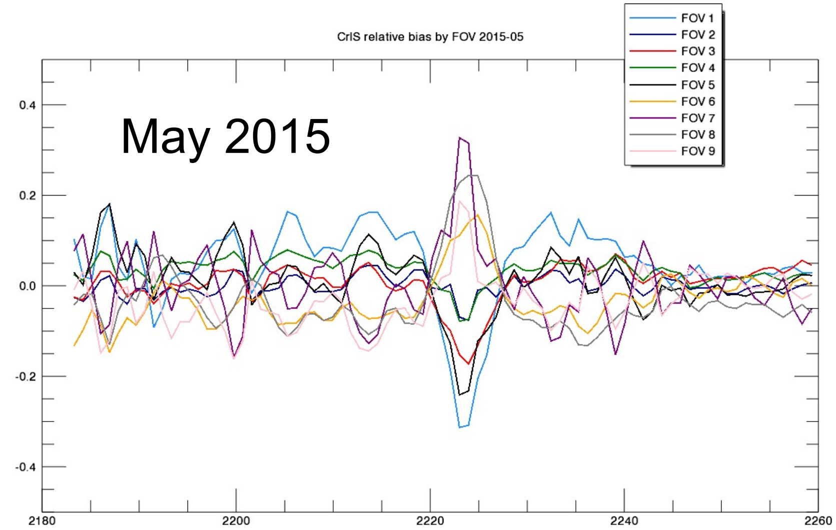
CrIS SW By FOV

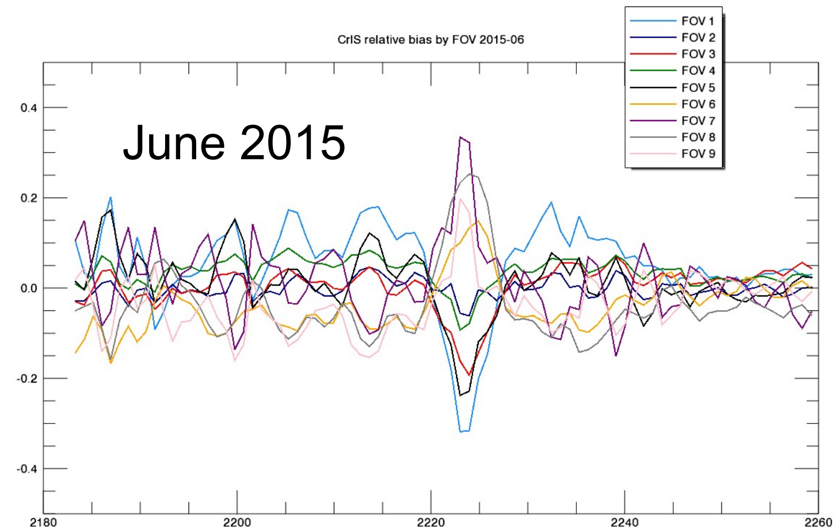


- Shortwave differences are largest
- There are >500 mK differences near 2224 and 2385 cm^{-1}.
  - Will be shown individually.
- Differences for >2400 cm^{-1} are not consistent across tests, so they probably represent differences among observations.

2224 cm^{-1}

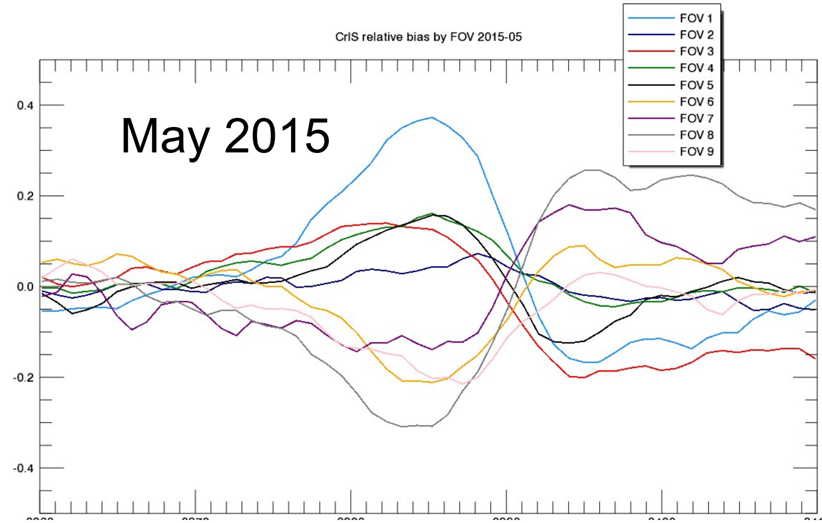
- The feature near 2224 cm^{-1} corresponds to a peak in the stratosphere.
- FOV 7 (purple) has the most positive peak bias: 300 mK greater than the average.
- FOV 8 (gray) also has a strong positive bias.
  - Its peak is lower but the peak is broader.
- FOV 1 (light blue) is the most negative.
- Biases are reversed outside of the peak.
- This suggests the issue is differences in spectral shift and SRF shape.

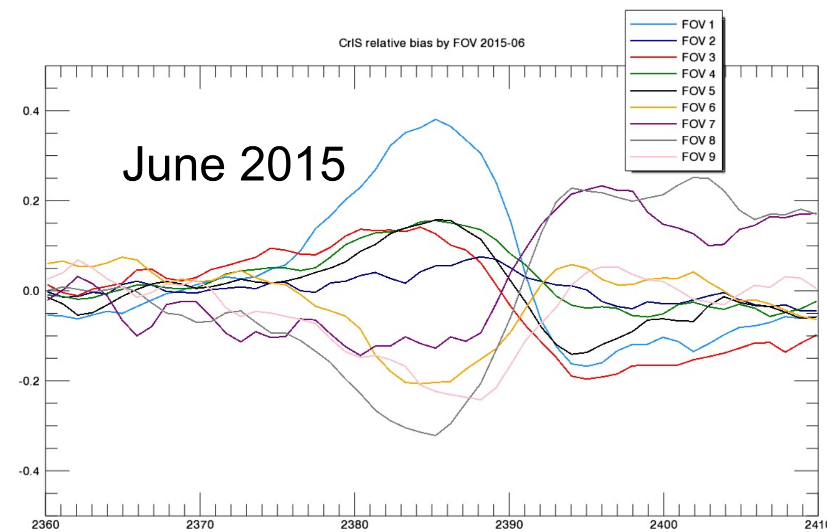


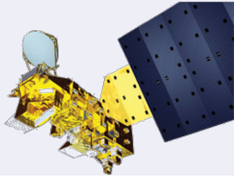


2400 cm^{-1}

- The feature near 2400 cm^{-1} corresponds to a sharp minimum at the tropopause.
- FOVs 1 & 8 are the extrema.
- There's a dipole pattern.
- This looks like a SRF broadness differences.



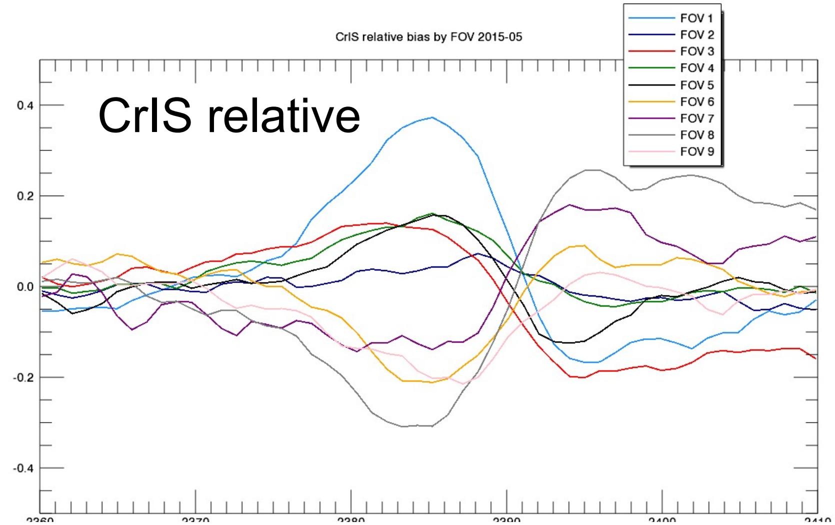


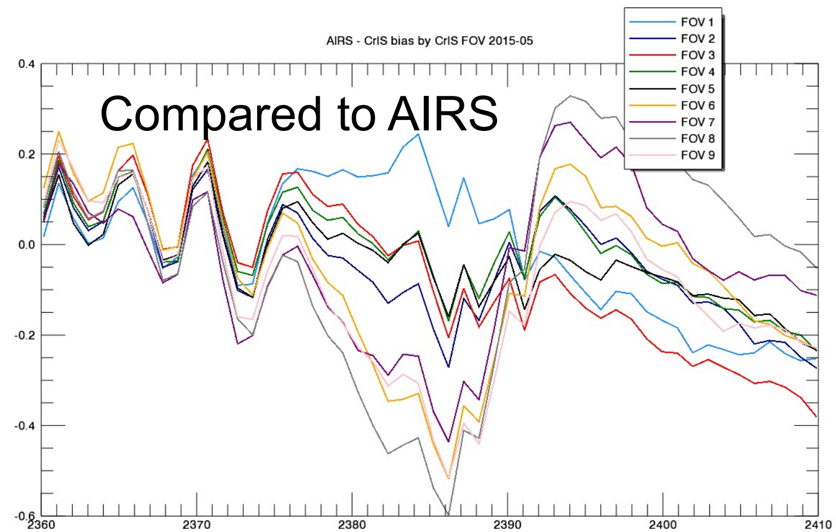


2400 cm^{-1}

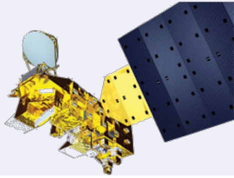
- AIRS agrees best with FOV #1 (light blue).

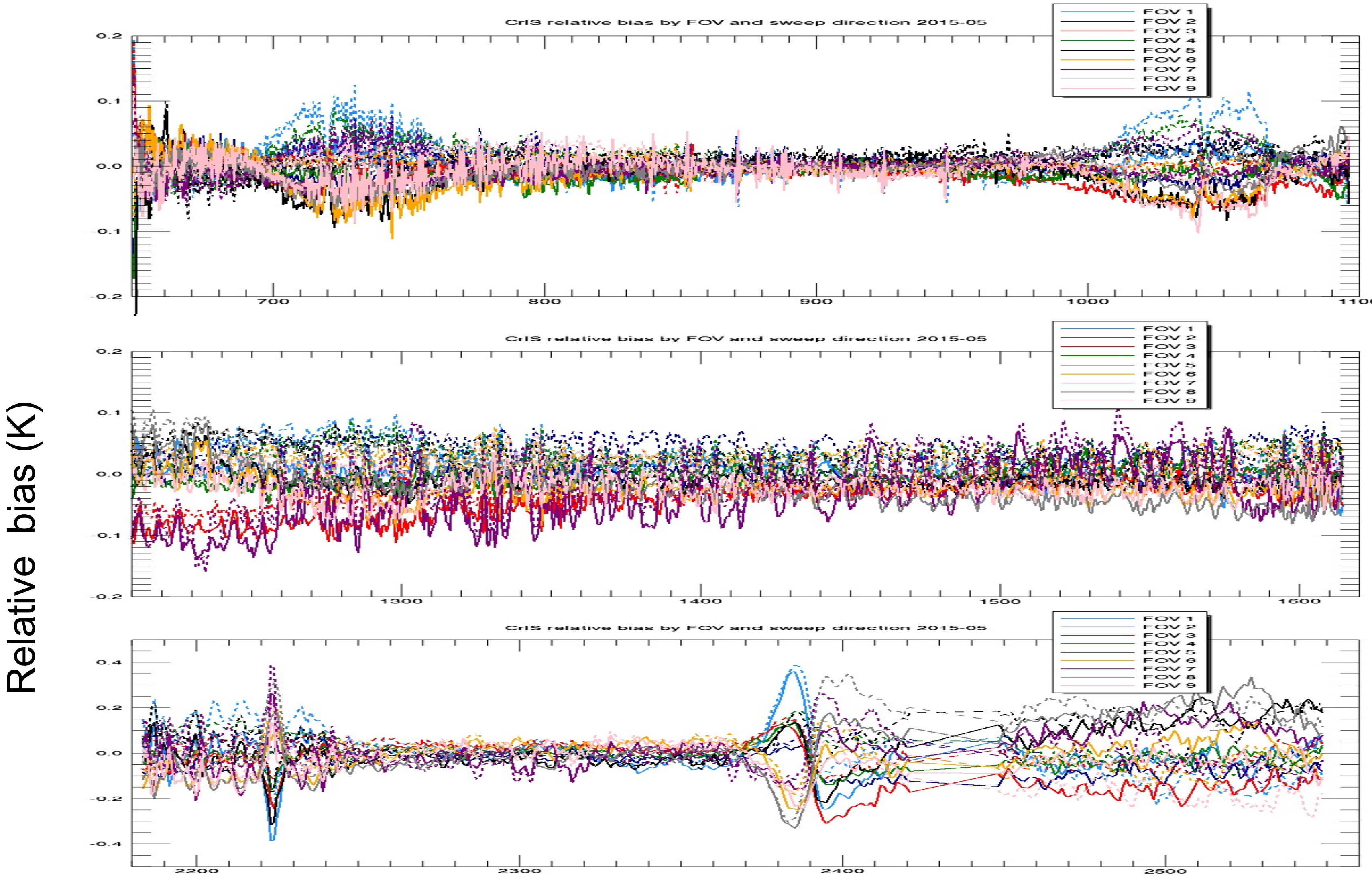
- But AIRS also has spectral shift and SRF shape uncertainty.



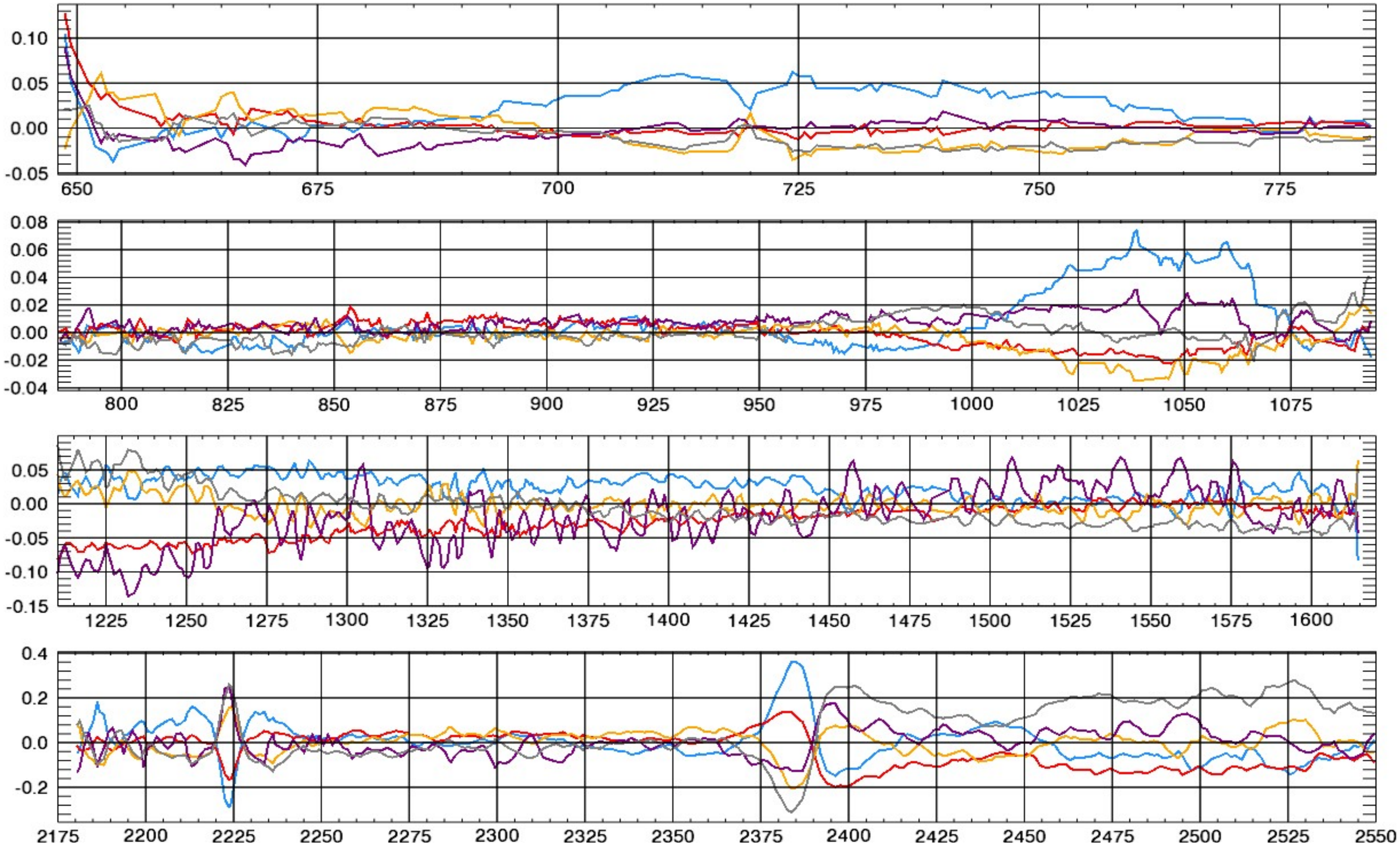


Also sweep direction





CrIS FOV diffs plotted “AIRS style”



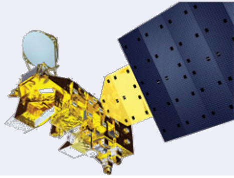
New tool: CrIS to AIRS

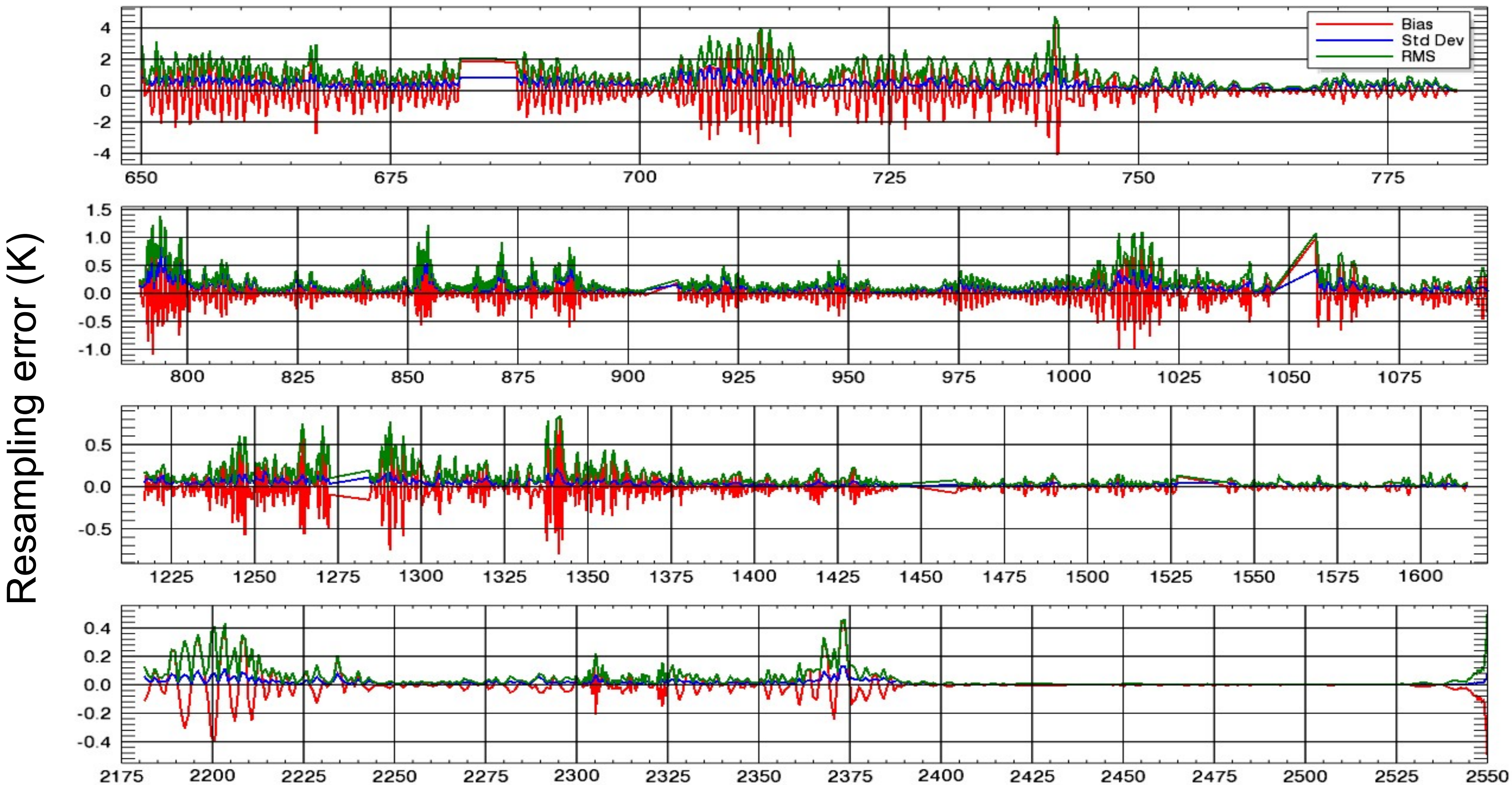
- Howard Motteler of UMBC has provided a version of the CrIS full-resolution TSNO spectra resampled to AIRS frequencies.

- This tool reduces the differences a great deal but care must still be taken, especially in the longwave band where AIRS spectral sampling remains denser than full-resolution CrIS.

- To quantify the errors Howard provided 47 sample computed spectra both as native AIRS and as CrIS resampled to AIRS.
  - We use the statistics of the differences between the two sets to understand the limitations of the comparison.
  - But these are only the **known** errors, assuming perfect knowledge of SRFs.

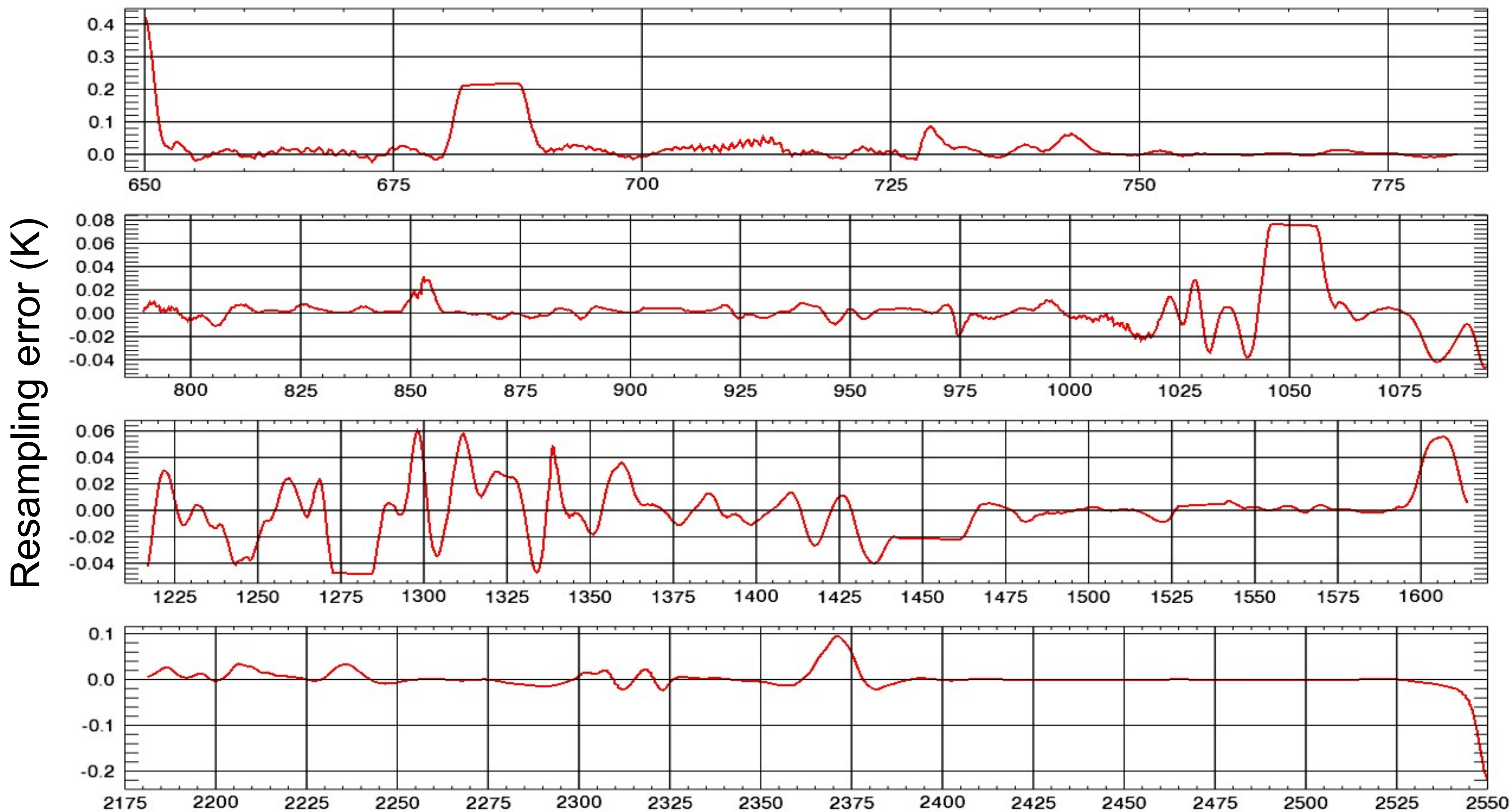
CrIS to AIRS resampling errors





- Resampling does well but can't match every AIRS channel, especially in the longwave, where AIRS resolution is still better.
- But the errors are oscillatory, so smoothing should help.

CrIS to AIRS resampling errors

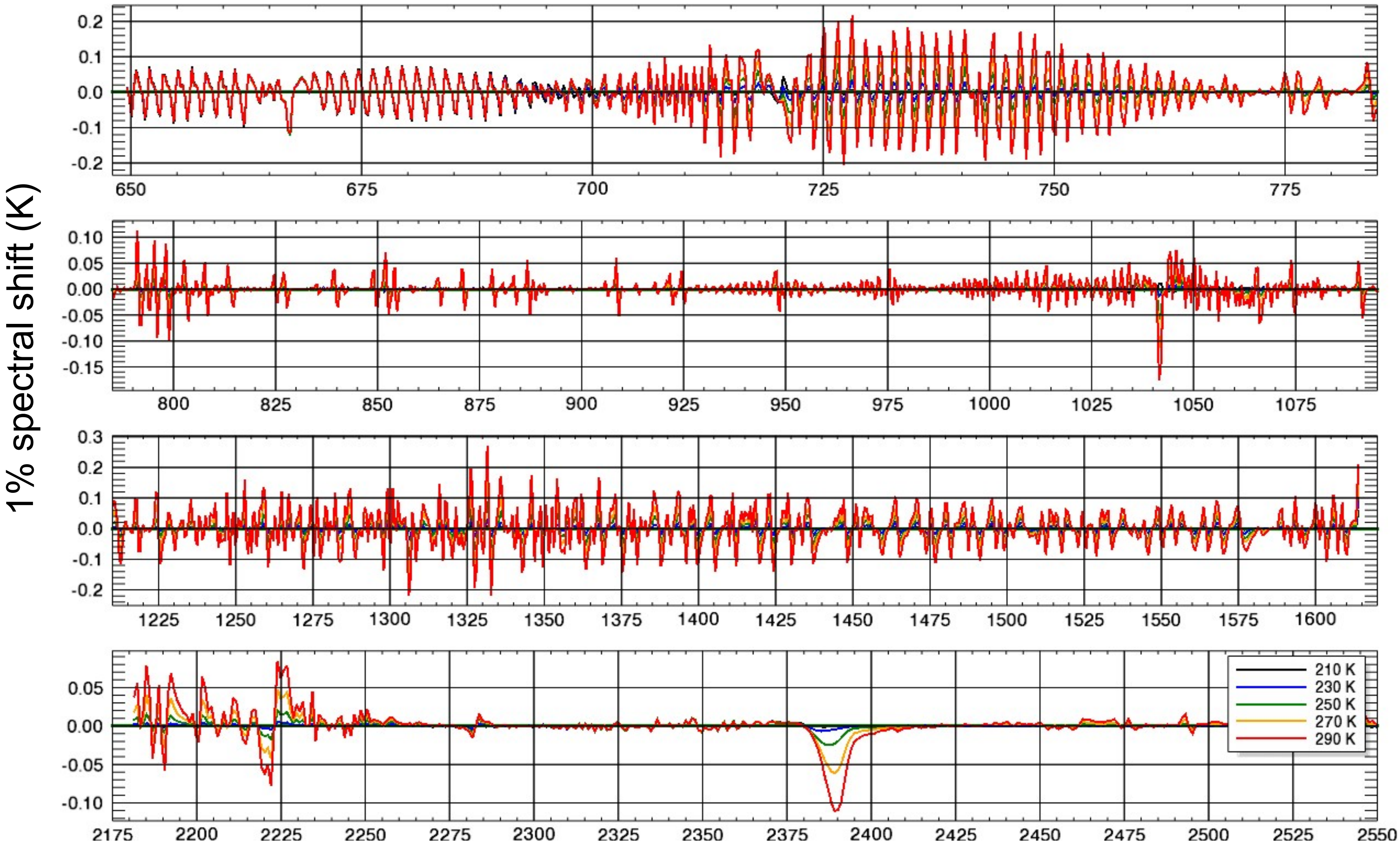


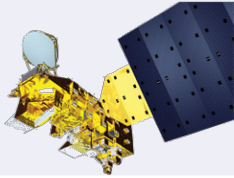
- Smoothing with a 7-channel-wide bell shape gets the errors below 100 mK everywhere

More mush: spectral shifts

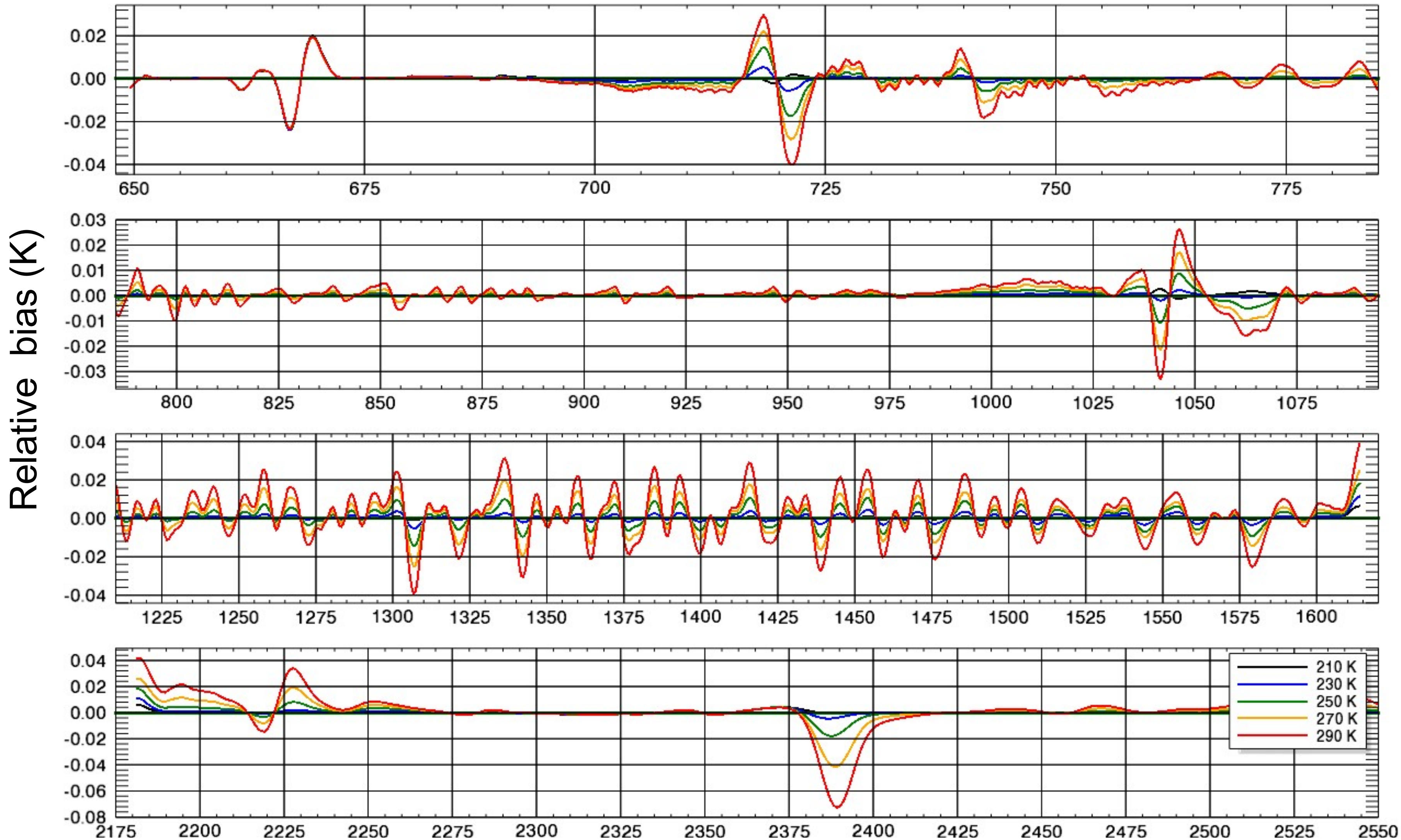
- One likely mismatch between AIRS and CrIS is a spectral shift.
  - AIRS spectral shift has changed over the mission and has an orbital cycle.
    - Individual channels shift slightly depending on whether they are using A and/or B detectors.
  - CrIS shifts may not be perfectly known.
  - CrIS->AIRS resampling assumed nominal CrIS shifts and resampled to nominal AIRS frequencies, even though AIRS in 2015 is not at its nominal shift.

Effect of a spectral shift 1% of AIRS channel spacing





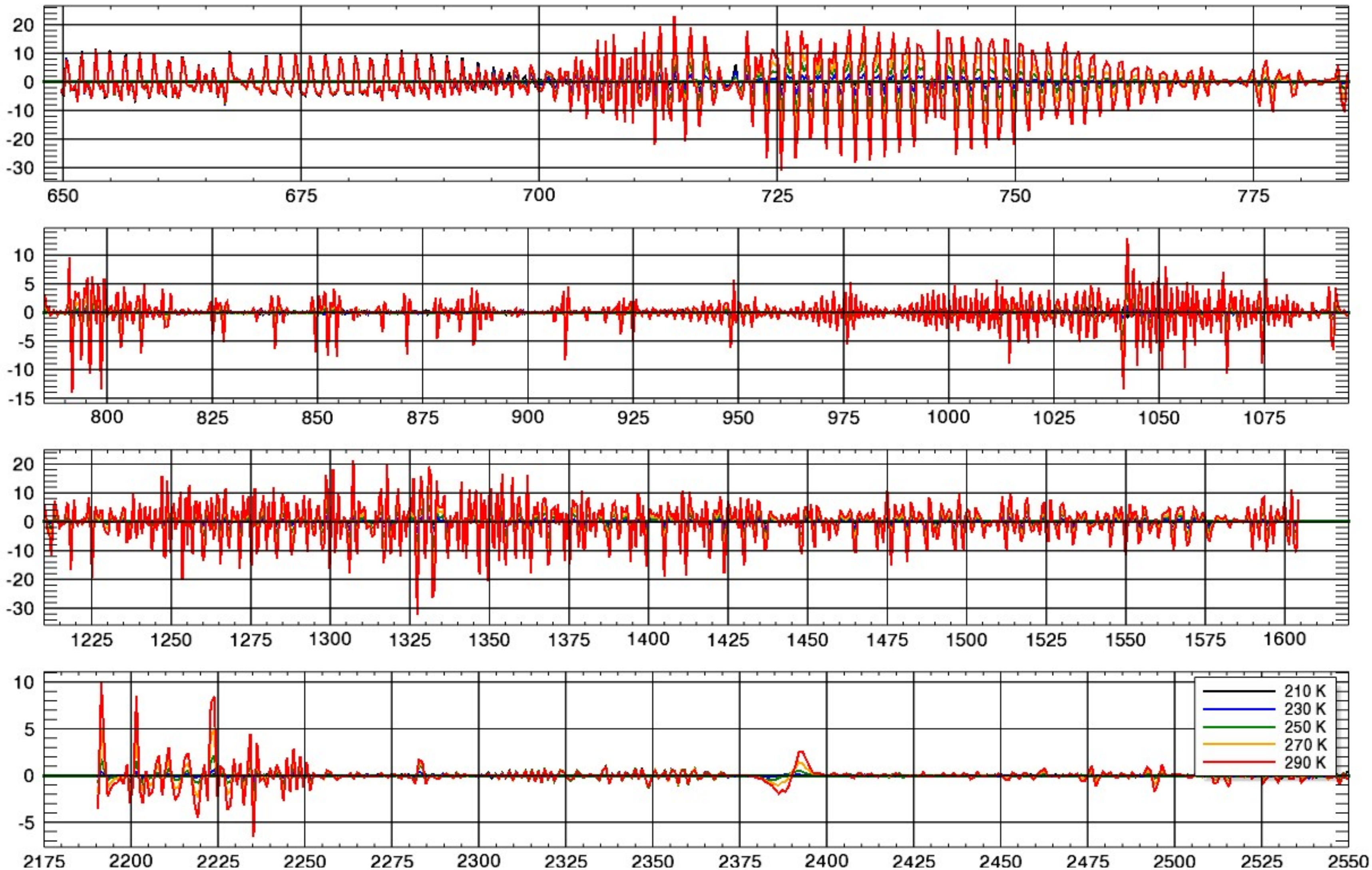
Effect of a spectral shift 1% of AIRS channel spacing – 7-chan bell smoothed



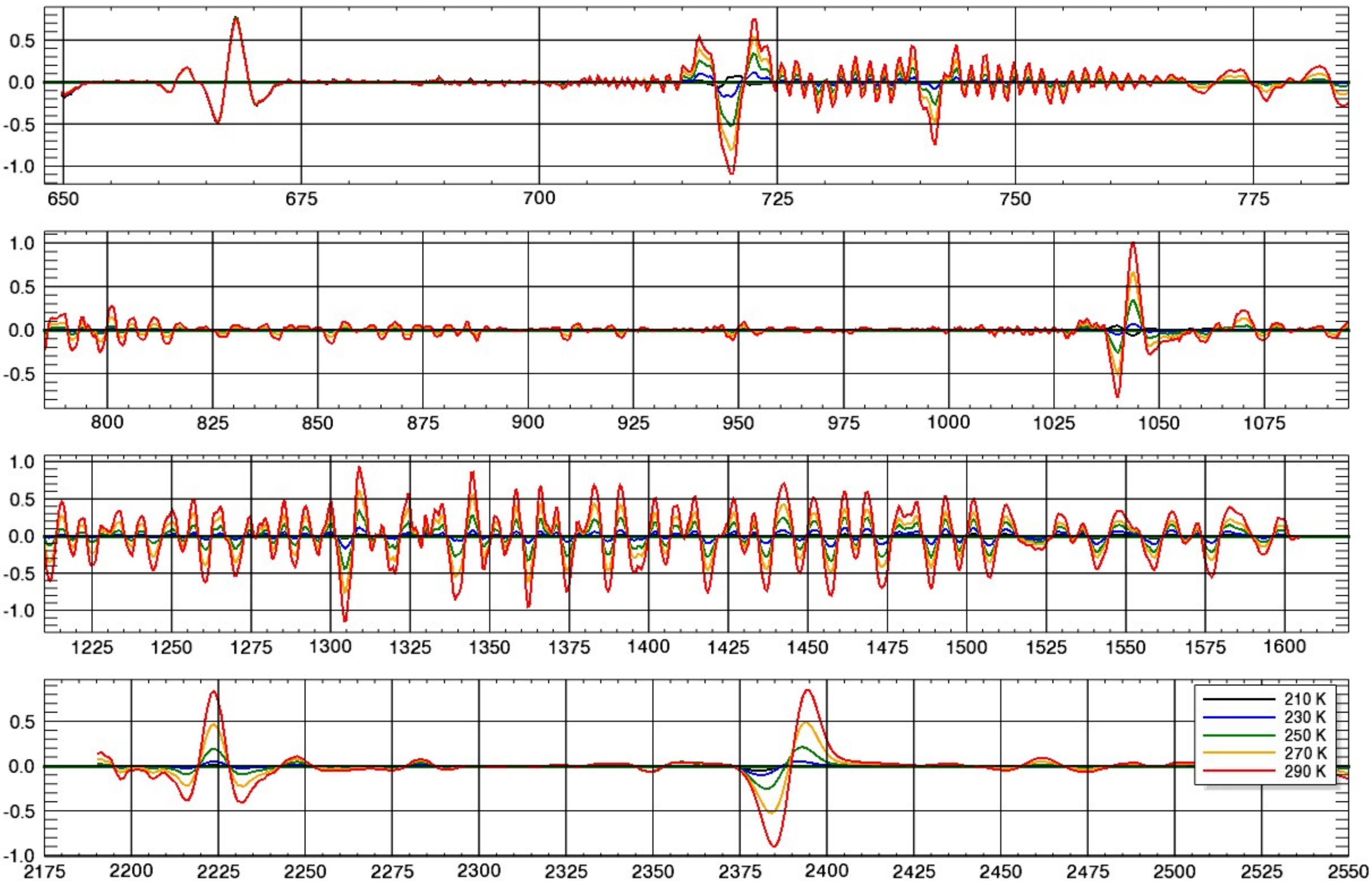
Second-order mush: SRF width

- Beyond simple spectral shift, there can be errors in the knowledge of the SRF shapes.
  - The primary mode will be that SRFs are slightly larger or narrower than expected.
  - This is crudely modeled as the second derivative (second difference) of a typical spectrum
  - Actual SRFs shape errors will be more like a combination of some shift and some width.

SRF width signal

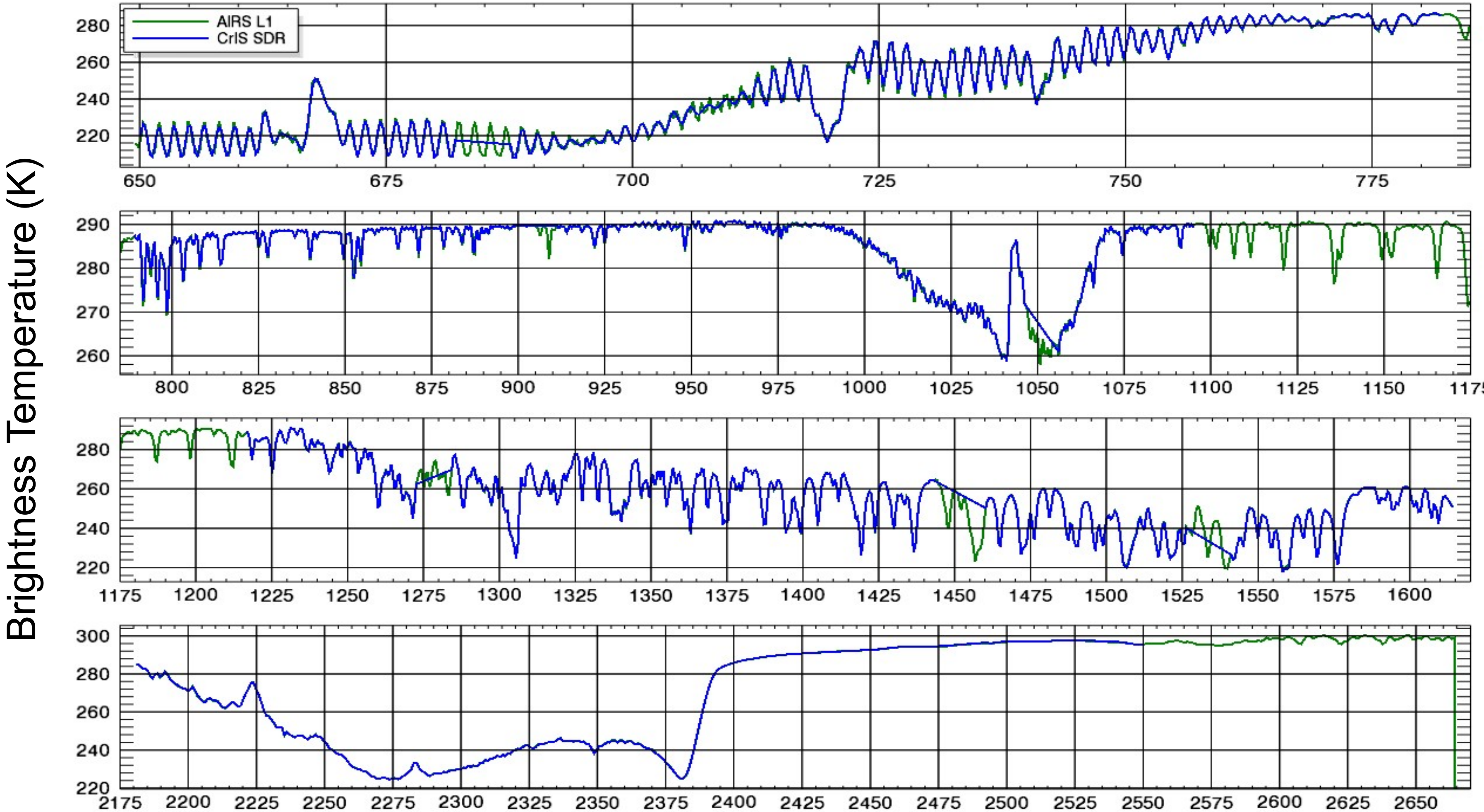


SRF width signal – 7-channel bell smoothed



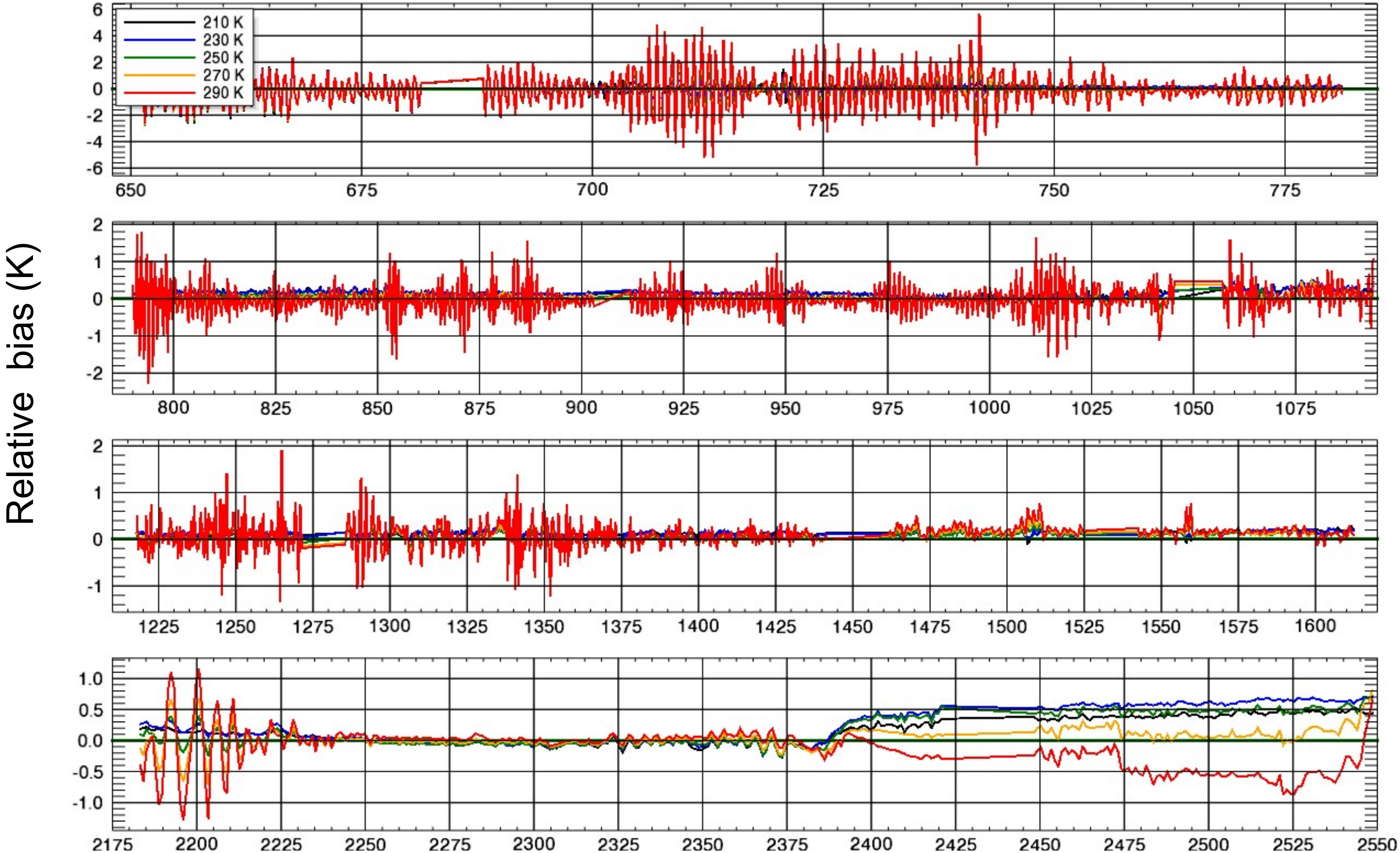
National Aeronautics and
Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California
Atmospheric Infrared Sounder

1-day comparison
AIRS vs full-res CrIS resampled to AIRS

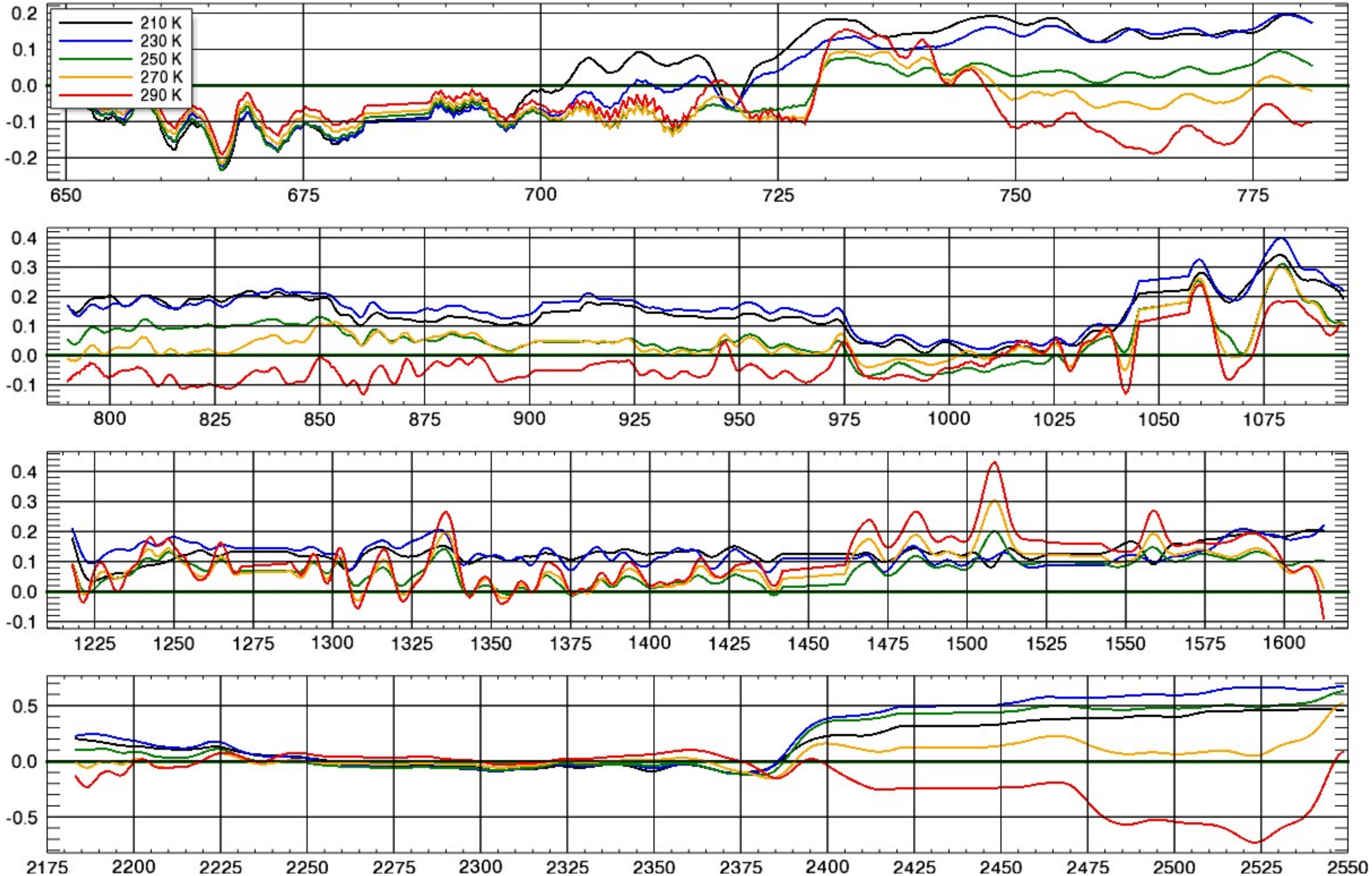


- At this level differences are not visible even without smoothing

Raw difference of AIRS and resampled CrIS by BT900



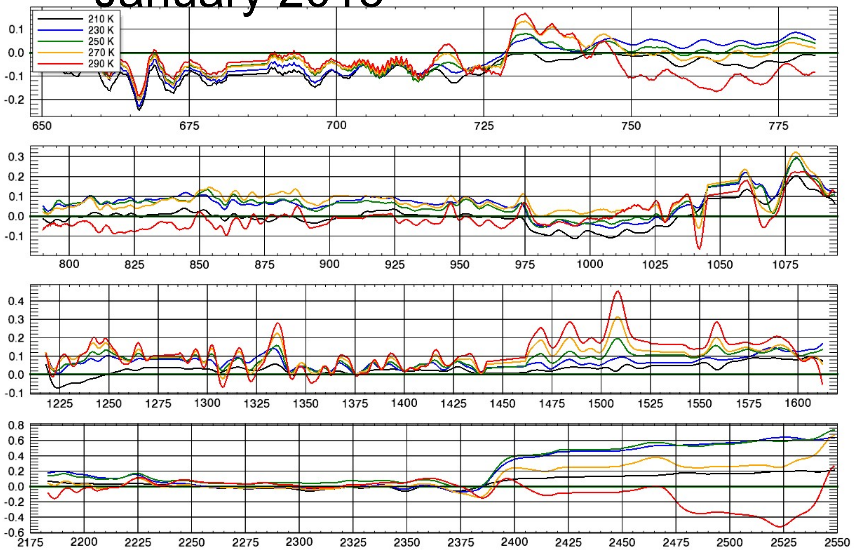
Smoothed difference of AIRS and resampled CrIS by BT900



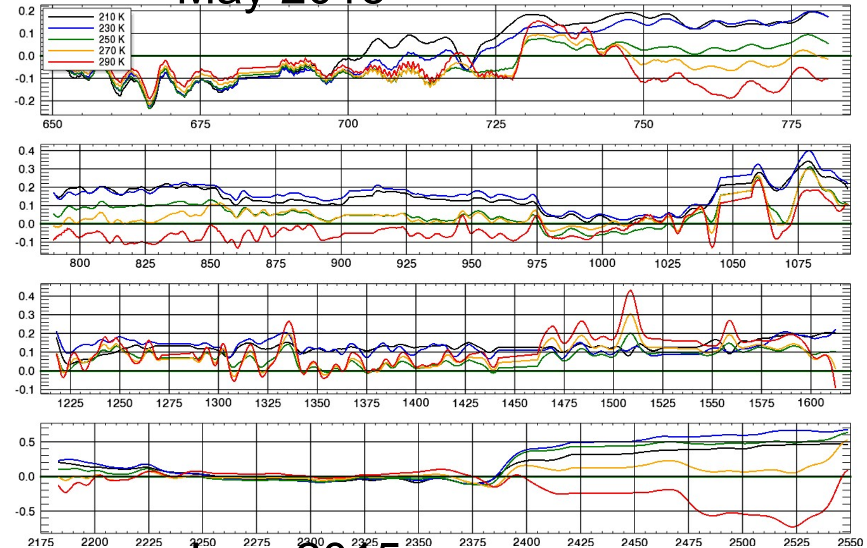
10/16/2015

3 months of AIRS - CrIS

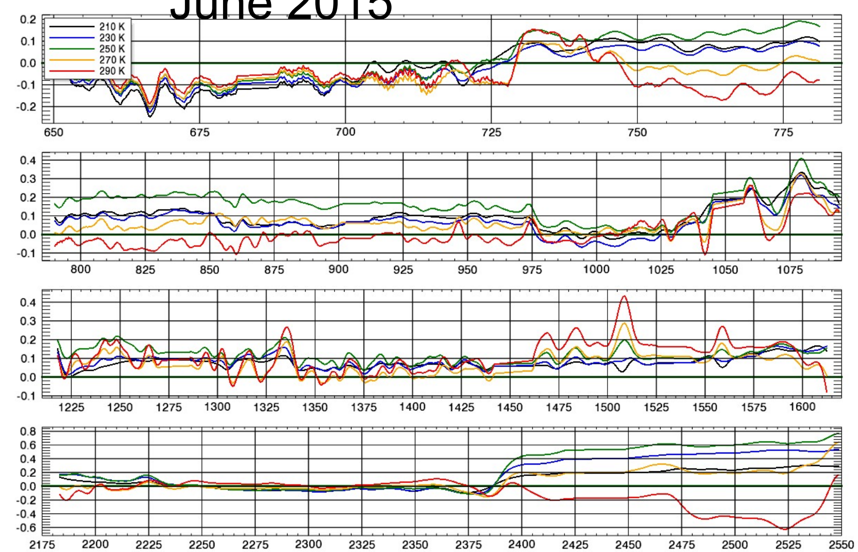
January 2015



May 2015

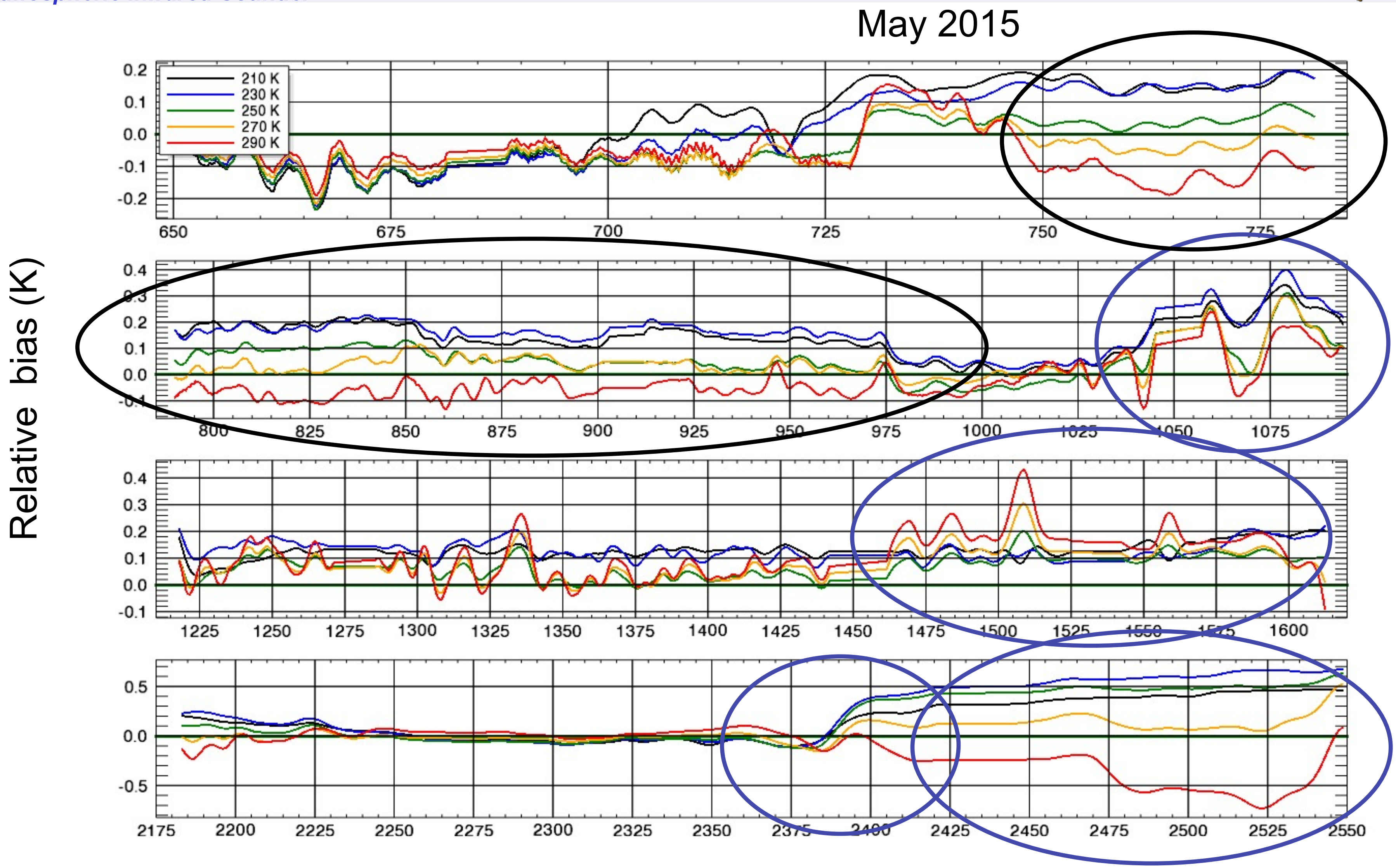


June 2015

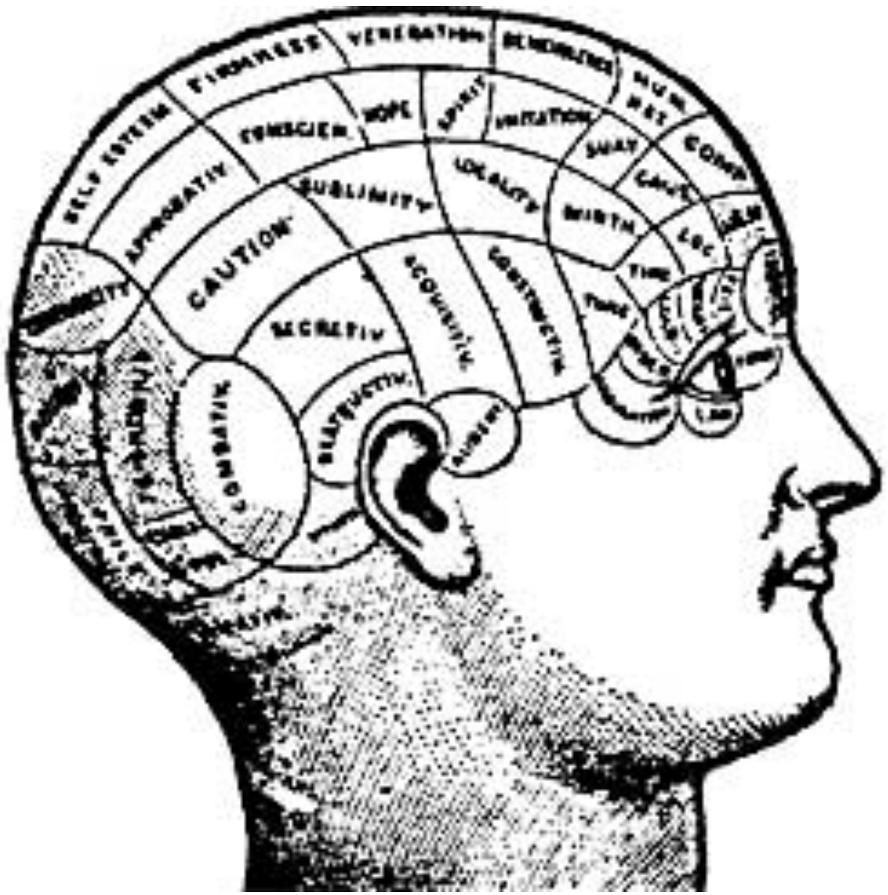


- Three months of comparisons differ significantly in important ways – more work is needed on merging datasets.
- Some common features are likely from resampling
- But some interesting features can be seen

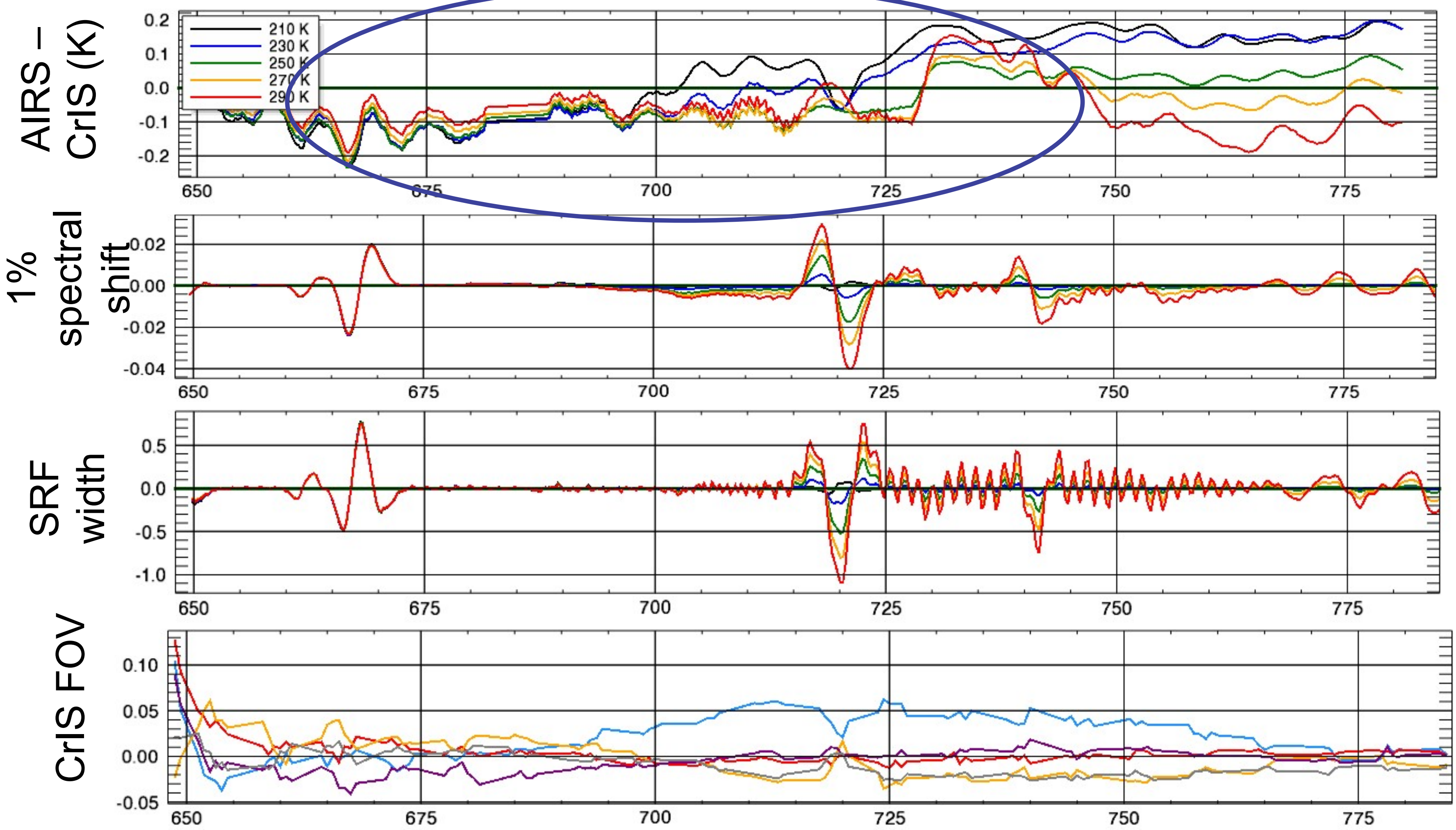
Features of interest



Spectral Phrenology

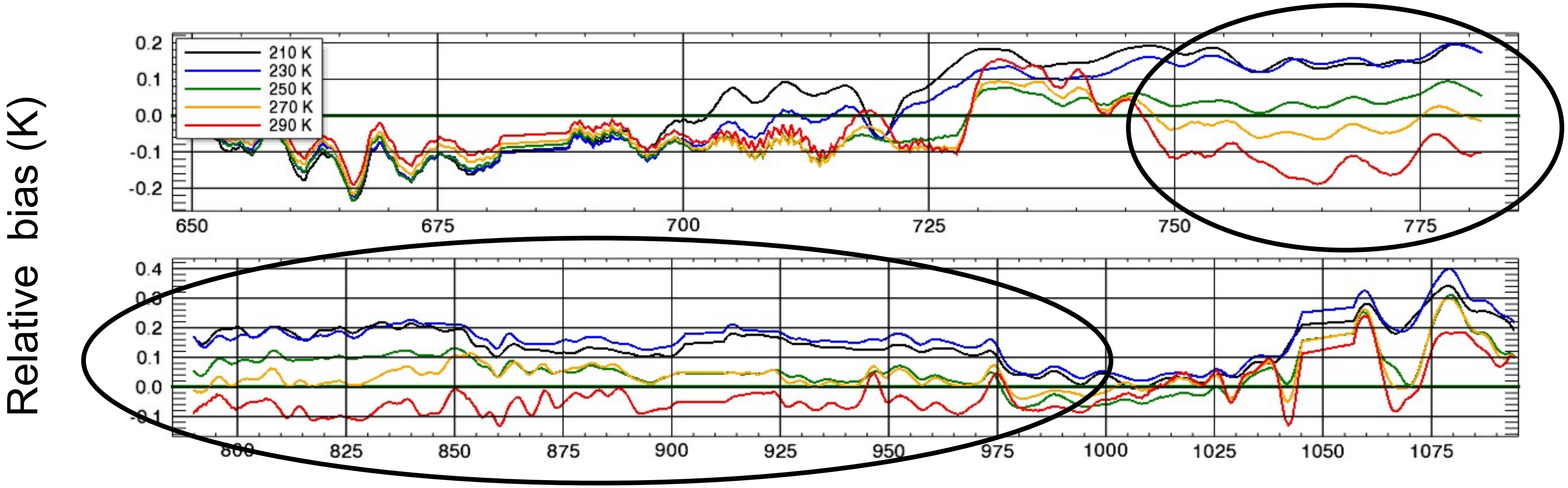


Warm-up: extreme longwave



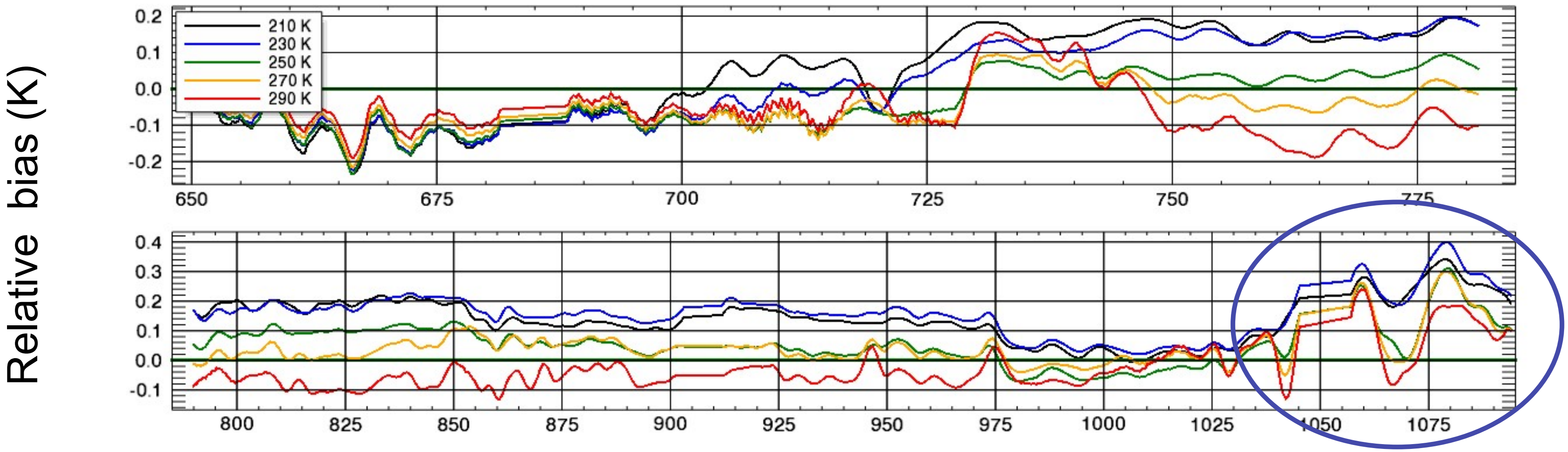
- The central feature at 720 cm-1 looks like SRF width for both AIRS-CrIS and CrIS FOV differences.

Features of interest – longwave window



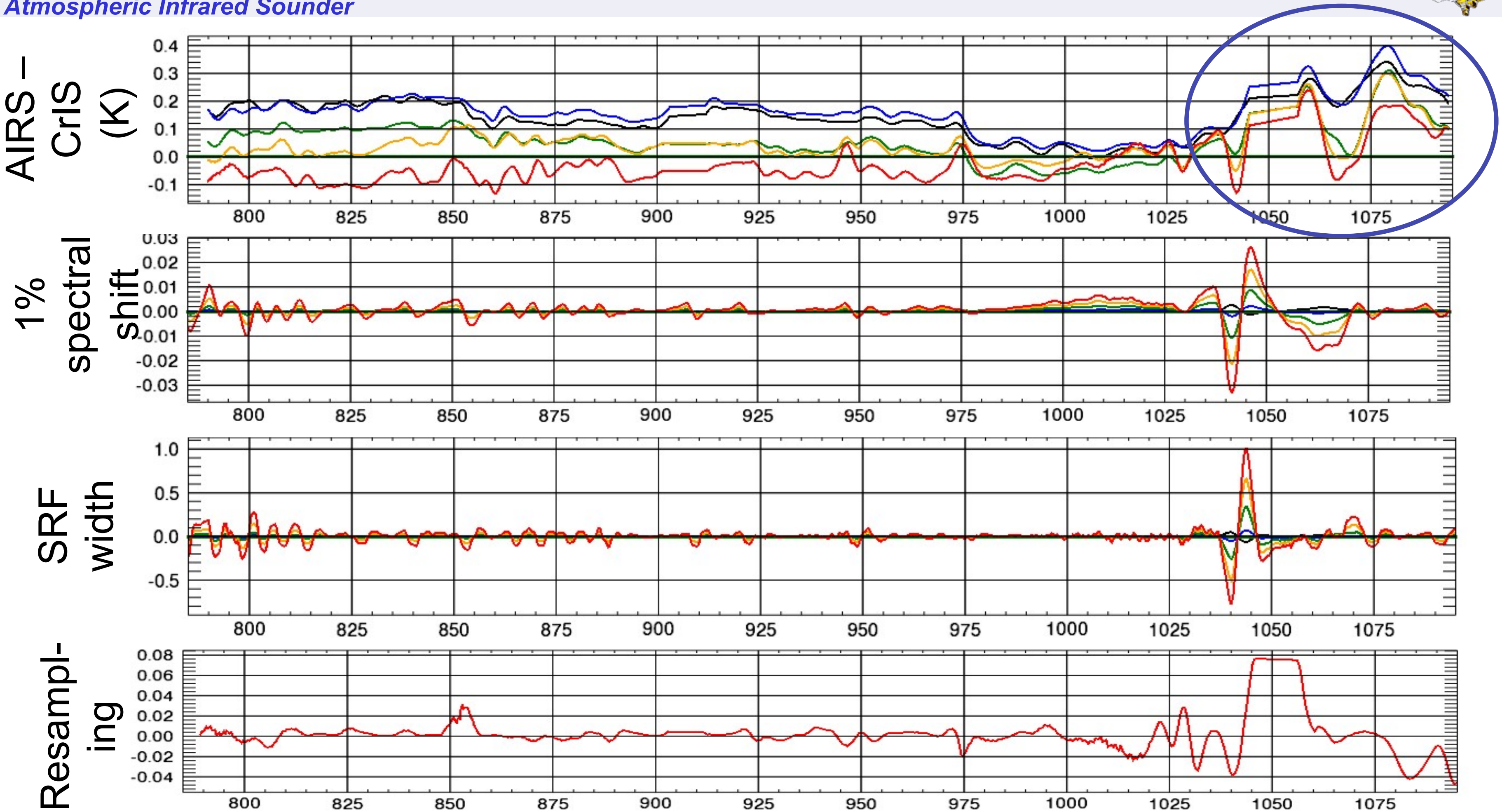
- There is a temperature-dependent bias throughout the 10-13 um window band.
- Biases are somewhat consistent:
  - For cold scenes AIRS is 0-200 mK warmer than CrIS.
  - For hot scenes AIRS is ~100 mK colder than CrIS.
- This suggests CrIS has a 0.4% wider dynamic range than AIRS
  - To some extent this is expected – CrIS is a step scanner while AIRS is continuous scan. So even though both have a 15 km nadir instantaneous FOV, AIRS has a larger effective FOV
  - So AIRS will see fewer scenes that are fully clear (hot) or 100% cold clouds.
  - **But** FOV size effects are not expected to be this large, so it may be a real calibration effect.
    - Note that there is near-zero difference near 270 K, the CrIS blackbody temperature

Features of interest – longwave ozone band



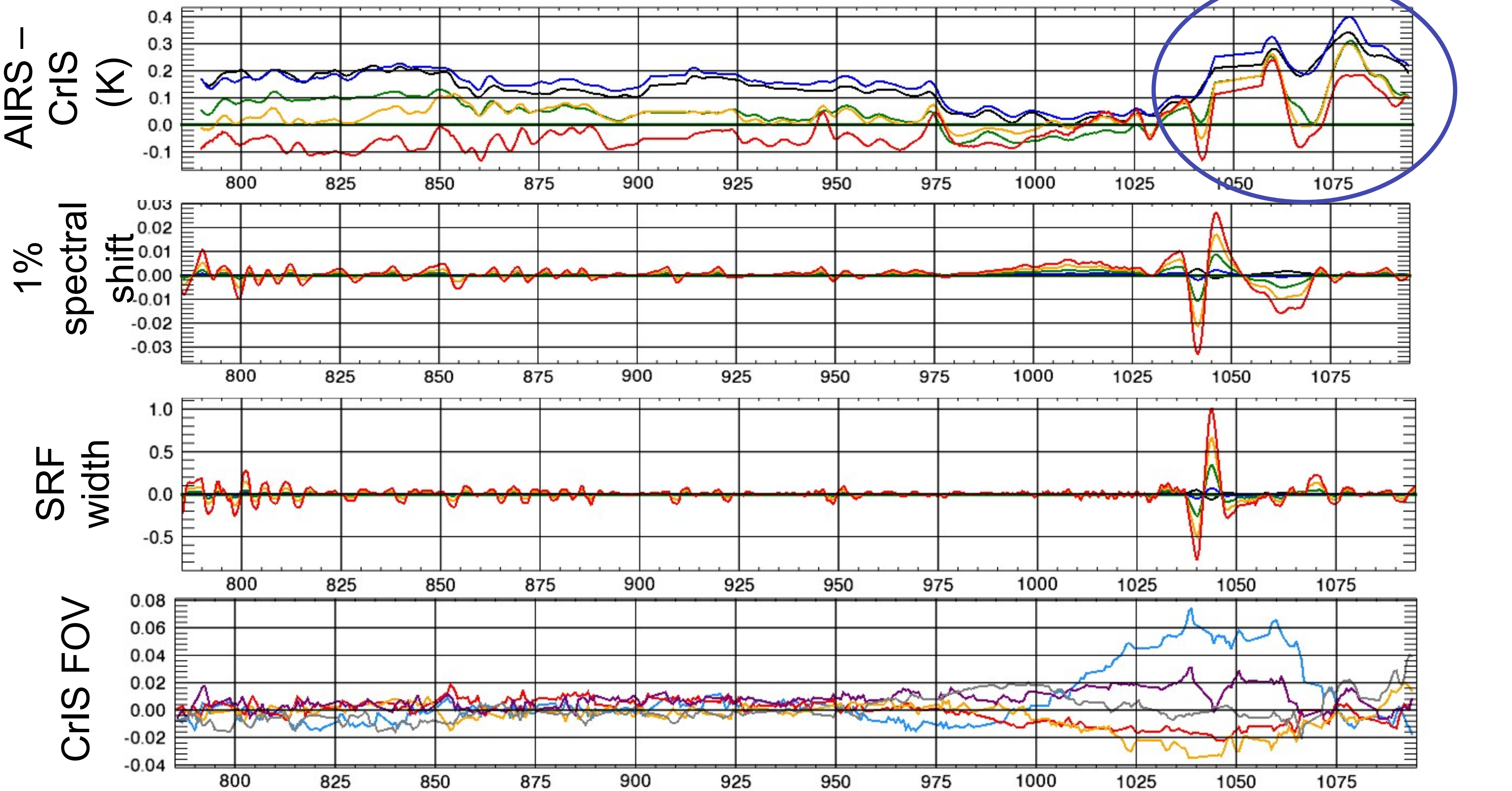
- There is a 100-200 mK bias (AIRS warmer) 1050-1080 cm^{-1}
- This could be partly a bias in AIRS module M-05

Features of interest – longwave ozone band



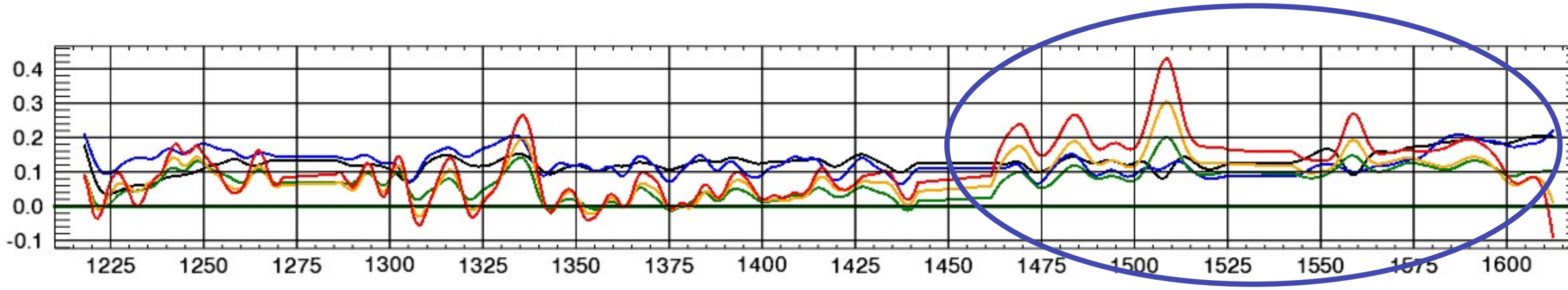
- Structure could be spectral shift plus (sign-flipped and amplified?) resampling

Features of interest – longwave ozone band

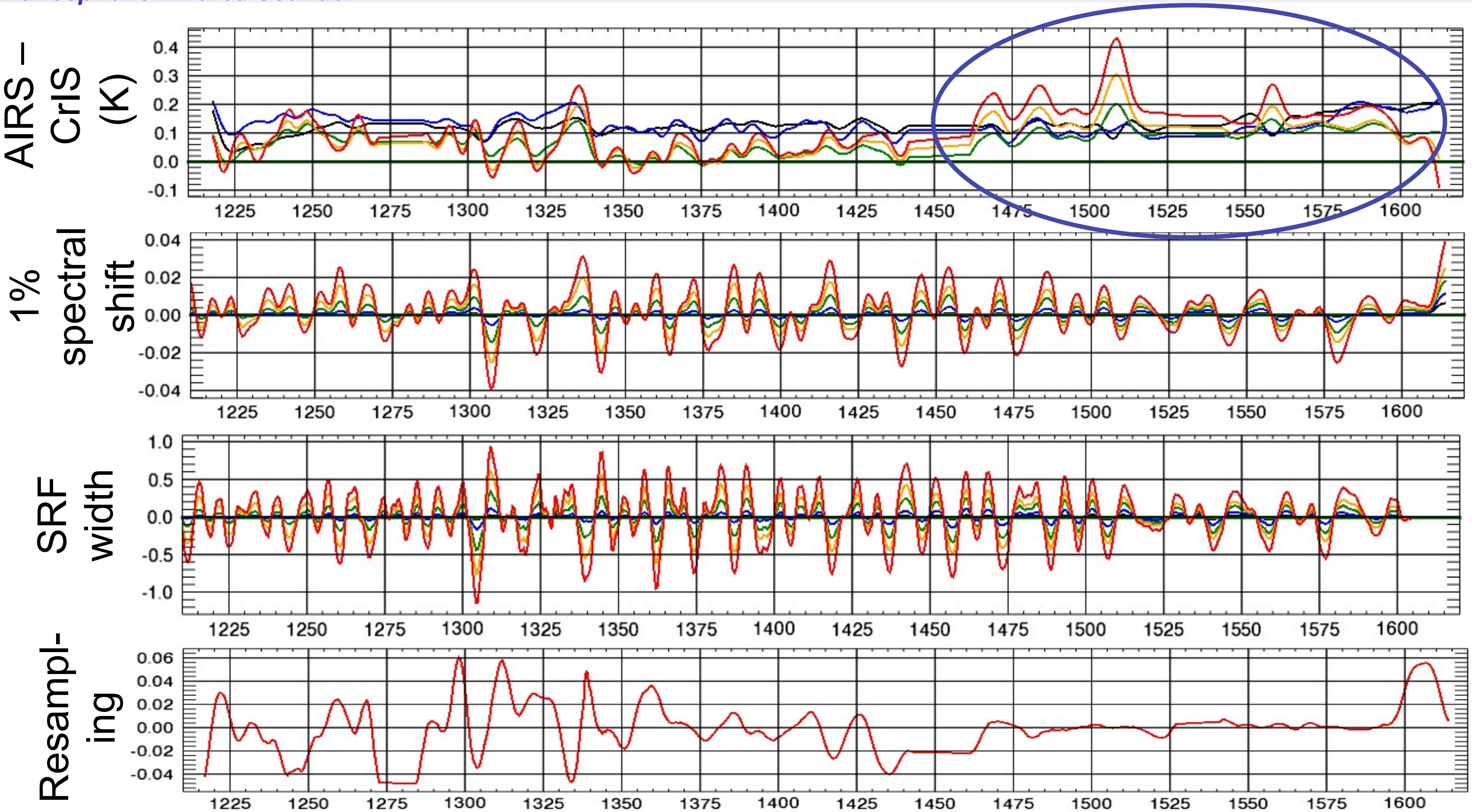


Features of interest - midwave

- There is a 100-200 mK bias 1475-1600 cm^{-1} (AIRS is warmer.)
- This could correspond to the slope seen across the MW band in some CrIS FOVs.
- Or it could be an AIRS problem in detector modules M-04a and M-04b

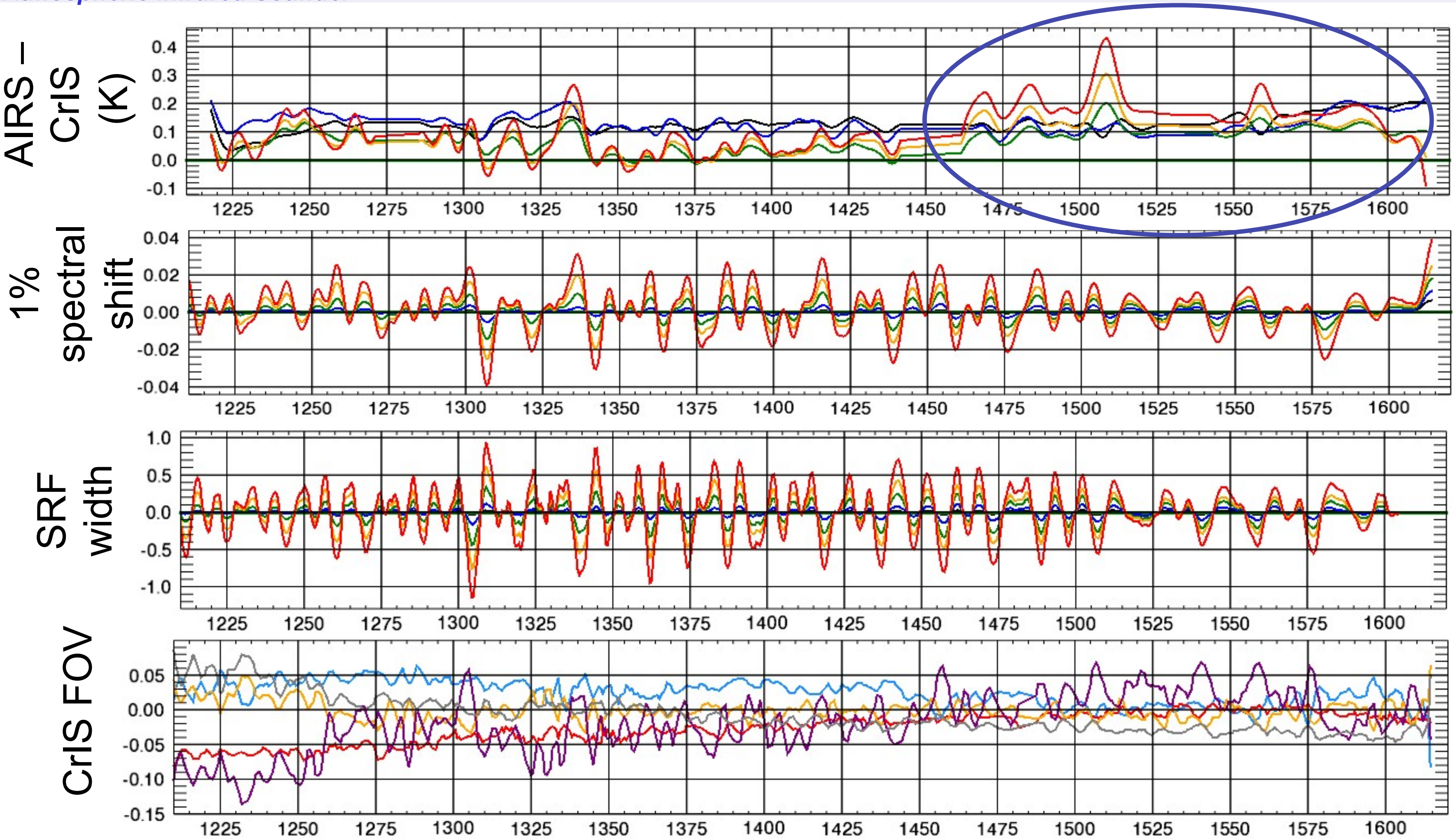


Features of interest - midwave



- The peaks and valleys only vaguely correspond to the candidates.
- So AIRS or CrIS instrument problems are most likely
  - Perhaps there are bad AIRS channels ~1508 and 1558 cm^{-1}?

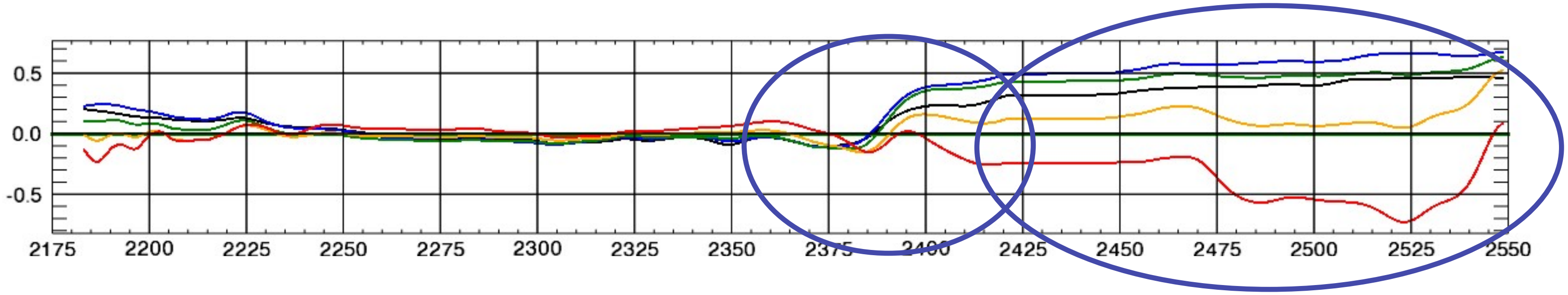
Features of interest - midwave

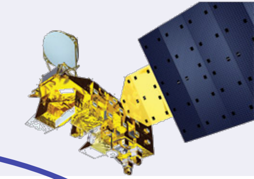


The large-scale pattern across the MW band may be similar to CrIS FOVs 3 & 7 slope

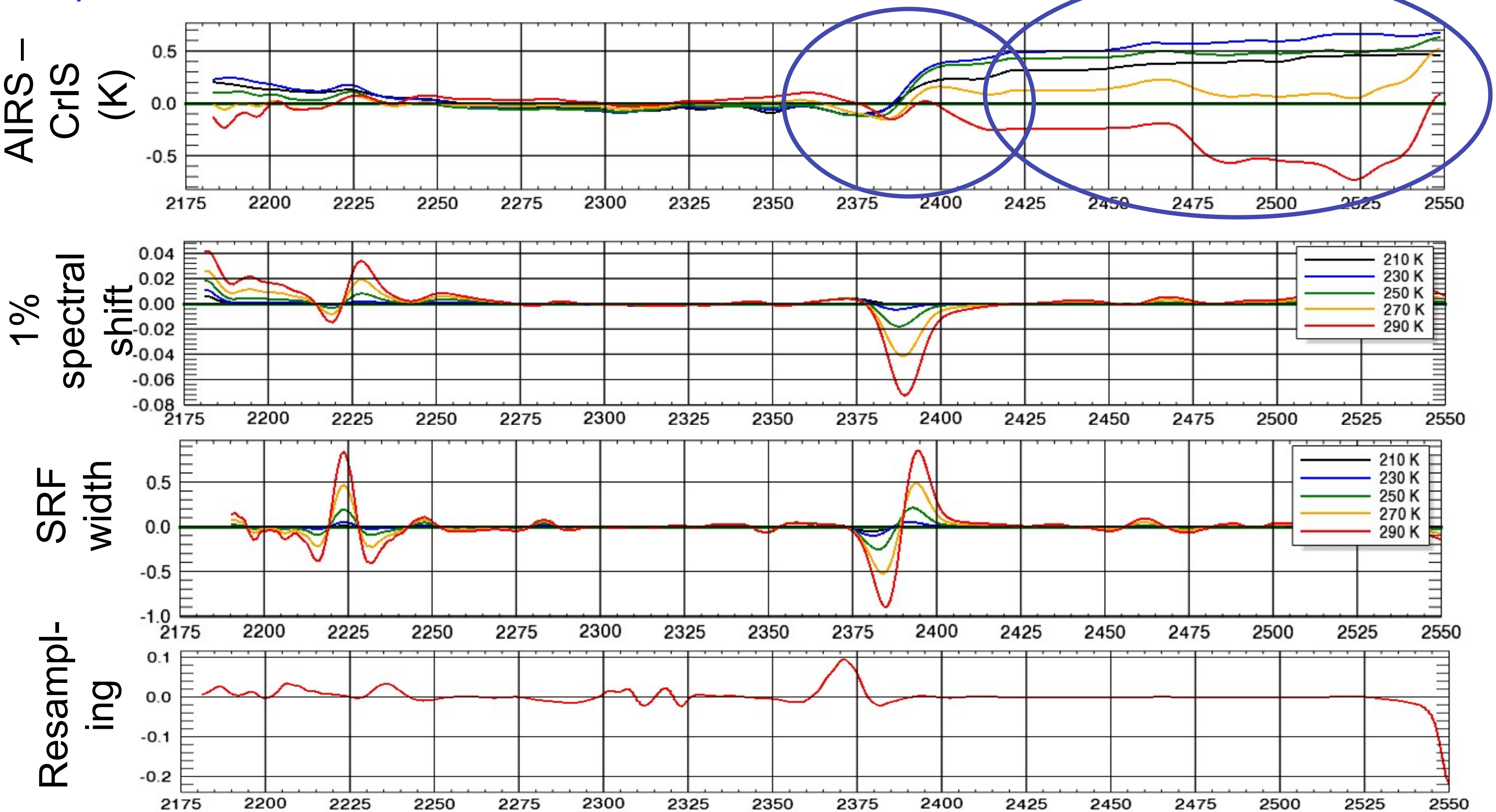
Features of interest -- shortwave

- There is a dipole feature near 2380 cm^{-1}, as seen among CrIS FOVs
  - This is probably still related to a spectral shift between CrIS and AIRS, but ascribing responsibility and fixing it will be difficult.
- The biases in the shortwave window seem related to the failure to sync window channels in the 11 um band.
  - But the biases here are much larger
  - There's a step at ~2475 cm^{-1} which is unexplained
- There are significant features at the shortwave end of all 3 bands. Coincidence?



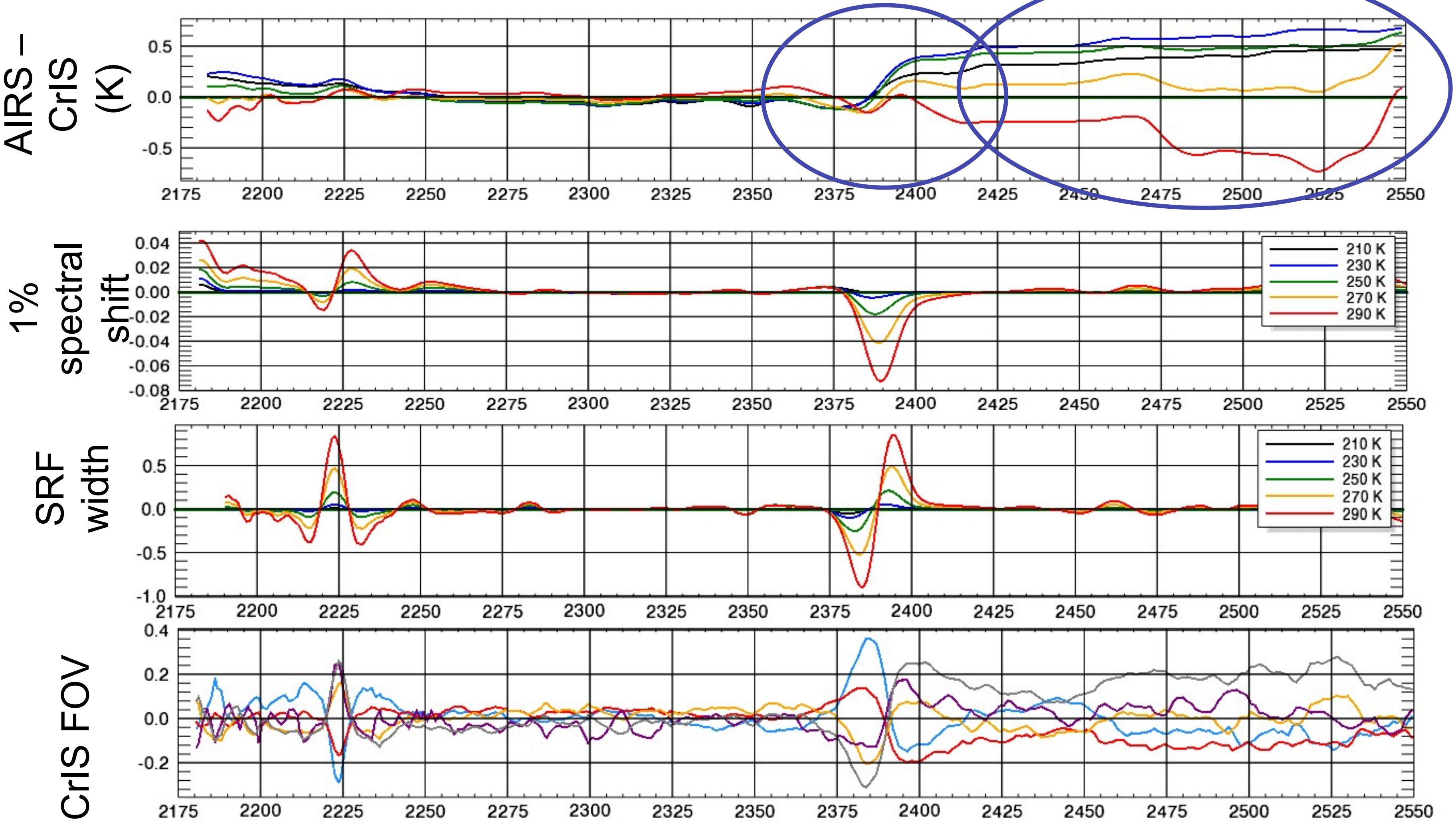


Features of interest -- shortwave



- SRF width matches the AIRS-CrIS somewhat.

Features of interest -- shortwave

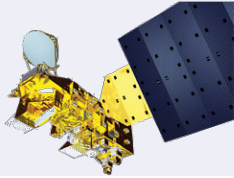


SRF width matches the SW features seen among CrIS FOVs well.

CrIS FOV Conclusions

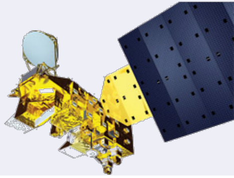
- CrIS has significant differences among FOVs in all bands.
- Shortwave and longwave differences seem to be mostly related to SRF shape.
- Midwave has linearity problems for FOV 7 plus a slope for FOVs 3 & 7.

AIRS vs. CrIS Preliminary Conclusions



- AIRS and CrIS have significant differences in all bands.
- Window biases may be an artifact of the current comparison methodology, but if not they are very significant.
- Most differences are probably related to errors in assumed SRF shape/centroid for one or both instruments.
- Some biases may be related to AIRS modules M-04a, M-04b, and M-05.
  - Others may relate to problems with individual AIRS channels.

Conclusions

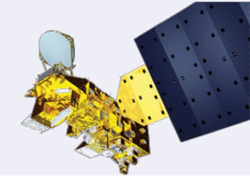


- TSNOs are a great dataset for understanding the AIRS and CrIS instruments.
- CrIS -> AIRS spectral resampling is helpful for exploitation of this dataset.
- Much more research is needed into the significant differences between AIRS and CrIS.

Further work

- Only 3 months of TSNO data with full-resolution CrIS has been generated so far, but several more months can be produced.
- Resampling may be refined.
- Some very suggestive correspondences are seen.
  - They should be analyzed quantitatively.
- AIRS/CrIS BT900 matching needs to be improved.
- Use CrIS to investigate known AIRS features:
  - M-08 A/B biases
  - Shortwave bias and trend

EXTRAS POST SCIENCE TEAM MEETING



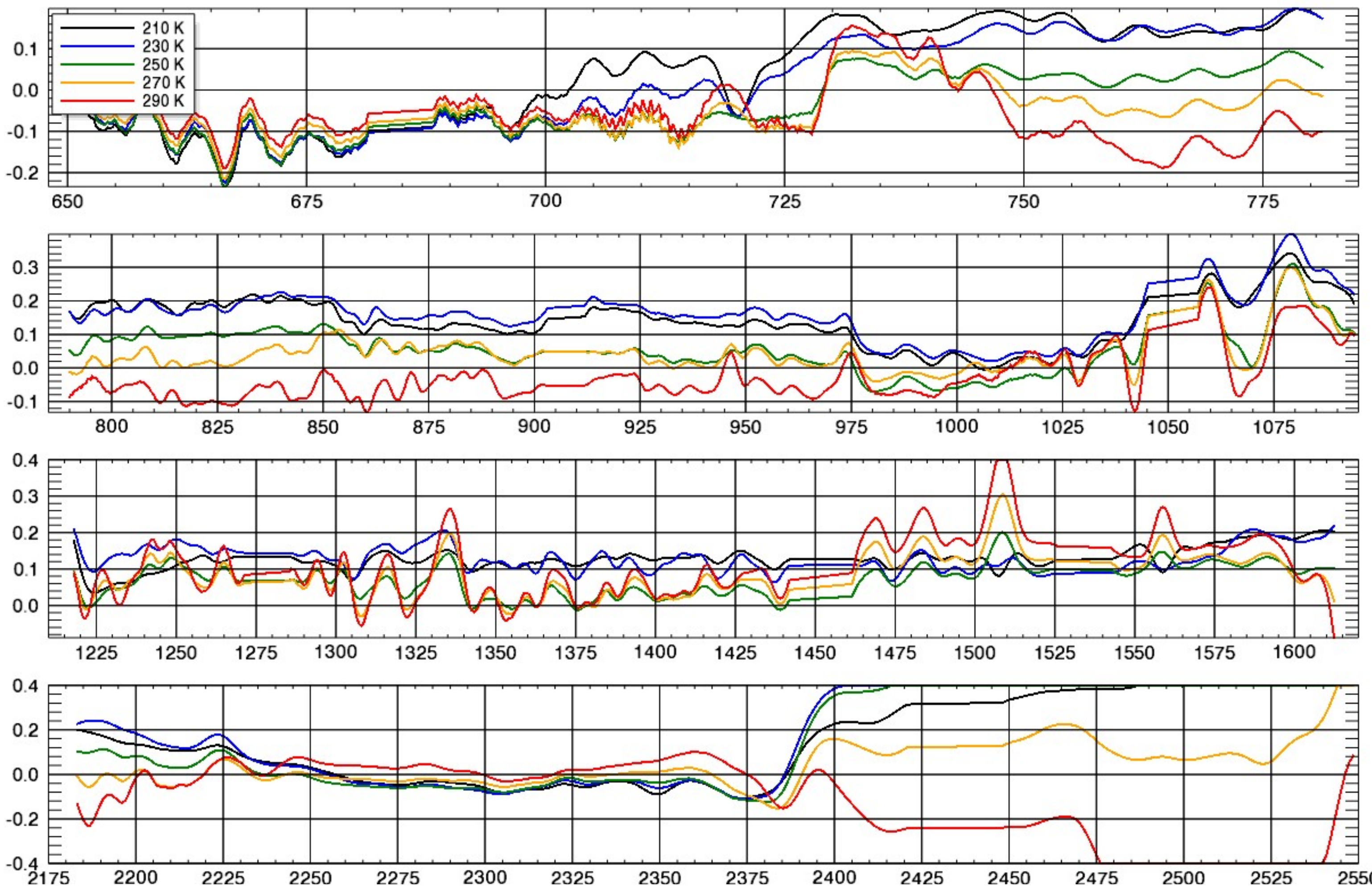
Window Biases

- One key issue in the original presentation was the question of whether the substantial AIRS vs CrIS temperature-dependent biases in the window regions could be attributed to geometric effects.
- I did a new run, crudely limiting the geometric effect by keeping abs(Inhomo850) in the homogeneous ¼ of the original data.
- Window channel biases are much smaller, indicating that it is at least largely a geometric effect, not an actual instrument difference.
- There's still a significant difference in the shortwave.
  - I believe this is probably still related to observation geometry, but the details are not understood.
- The effect needs to be fully characterized and compensated.
  - It needs to be minimized for future versions of this TSNO analysis so we can focus on actual instrument effects
  - There also needs to be a full characterization so AIRS and CrIS can be combined into a single long-term record of extrema.

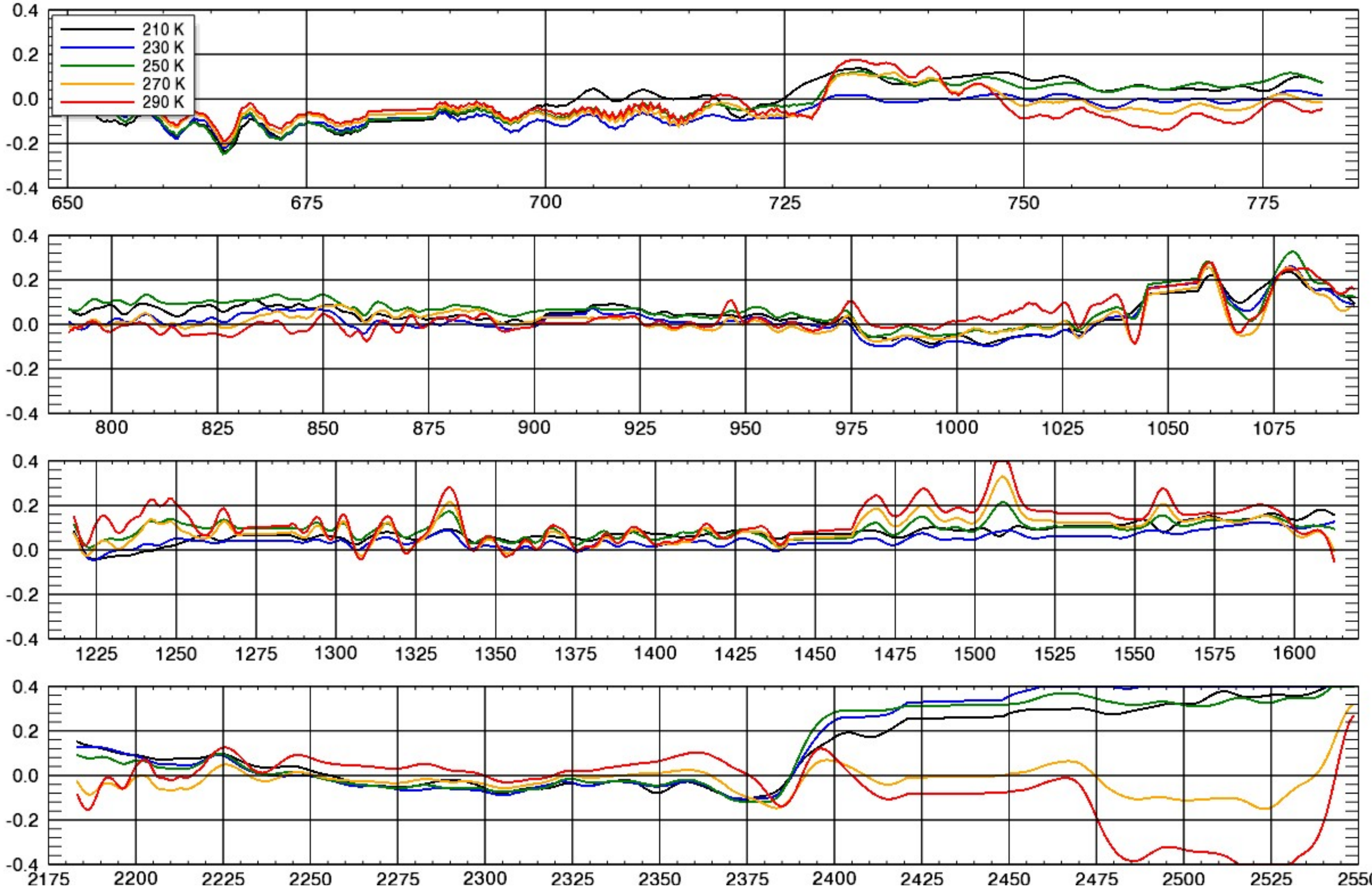
- The next 2 slides are meant to be flipped between.

- Note that the scales are not the same, which makes the reduction look greater than it is, but the spread at 900 cm^{-1} for example is still reduced form ~200 mK to less than 100 mK

Original smoothed AIRS-CrIS



Uniform smoothed AIRS-CrIS

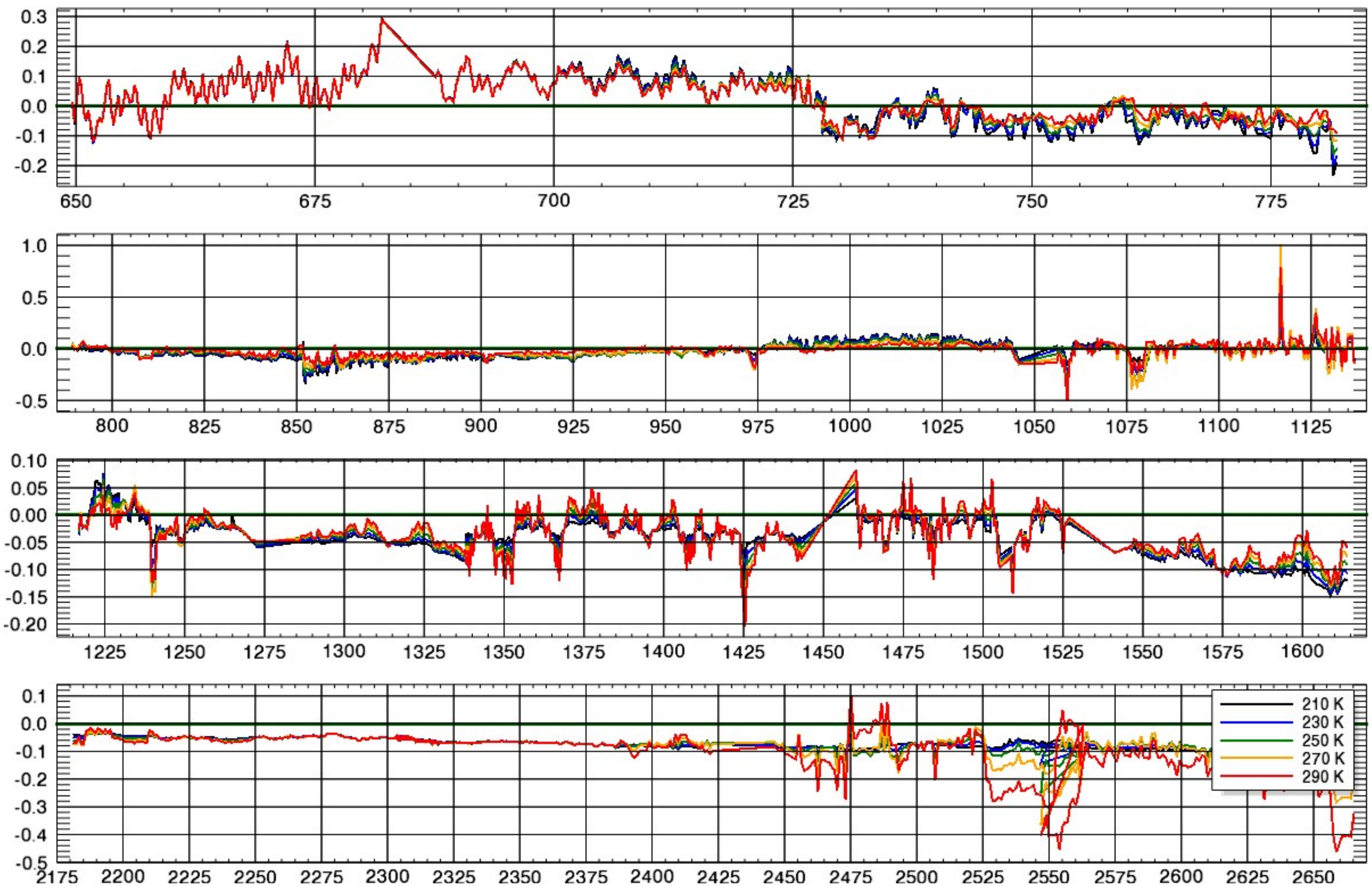


N40rab

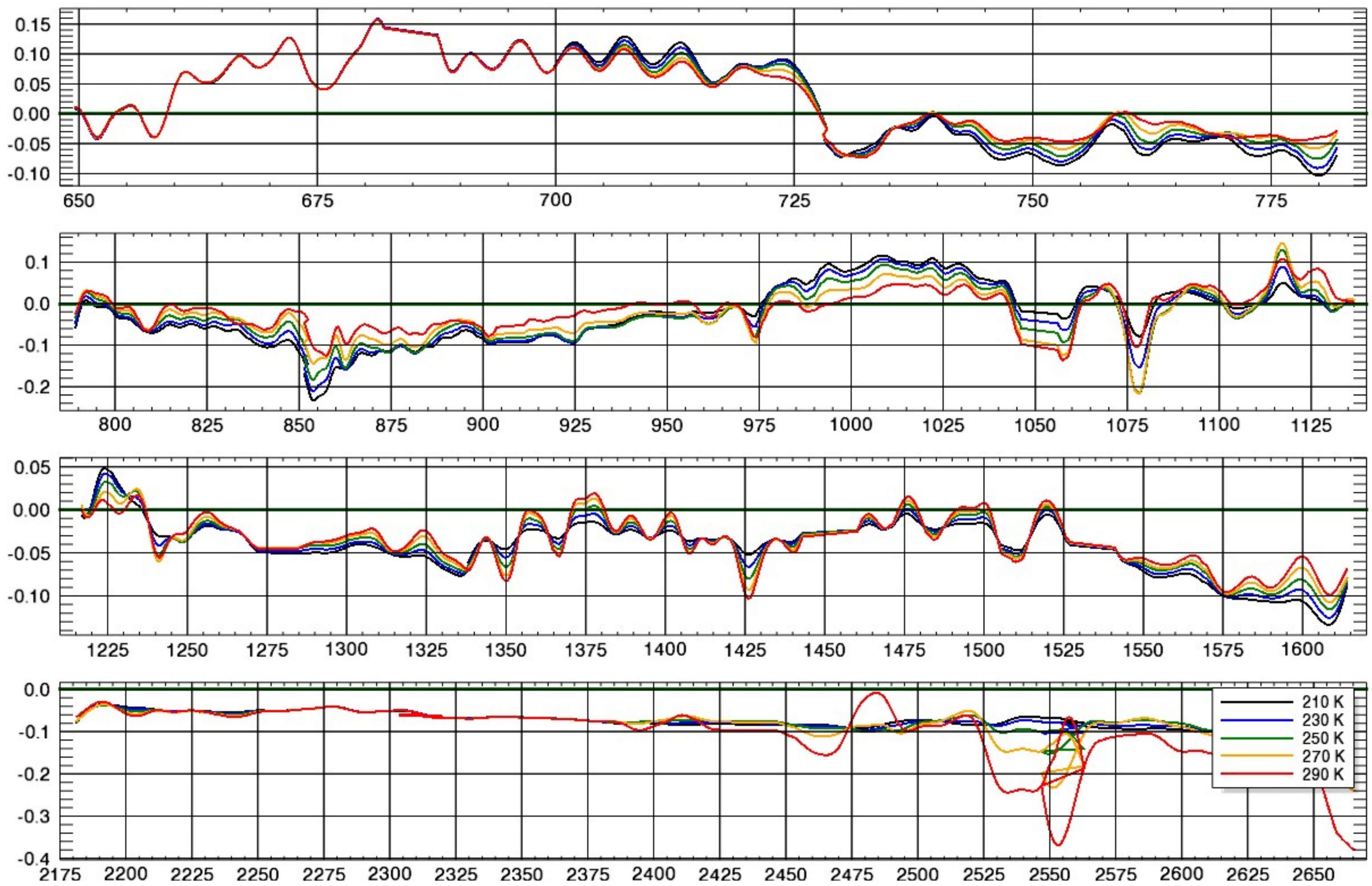
- Another important question is whether some of the AIRS/CrIS biases shown with AIRS v5 L1B might already be addressed with the candidate AIRS v7 L1B calibration.
  - This calibration, called "N40rab", takes into account varying polarization and differences between AIRS A and B detectors better than v5.

- I differenced v5 tropical night ocean nadir data with a test run of N40rab (next slide) and smoothed it (slide after next).

N40rab tropical night ocean delta



Smoothed N40rab tropical night ocean delta



N40rab

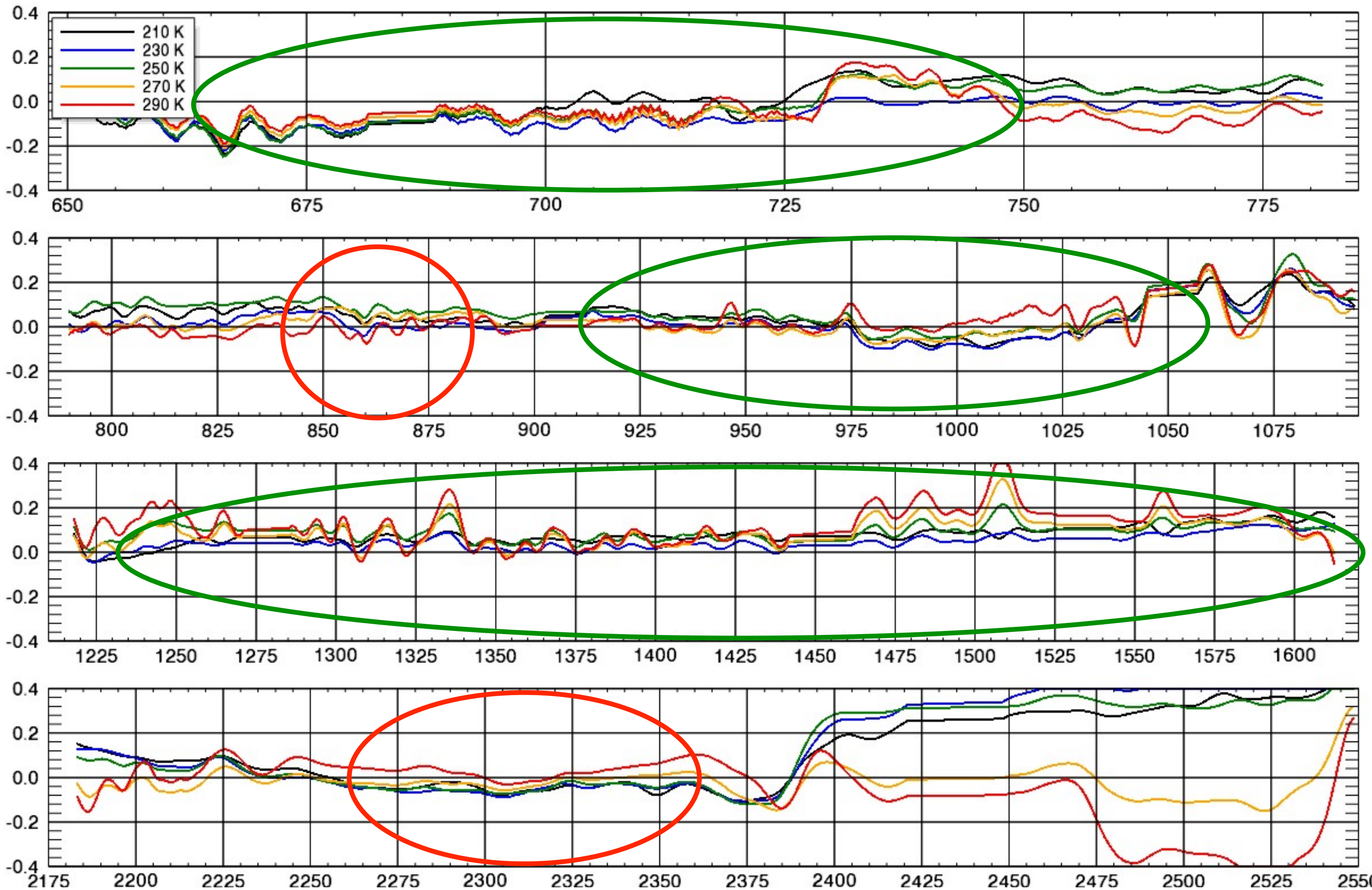
- We can now add the N40rab differences to the AIRS/CrIS differences to see approximately what would be the differences between CrIS and an updated AIRS.

- The next slide shows the same CrIS vs. AIRS v5 differences on uniform scenes shown earlier (p. 50).
- The slide after is the same but with N40rab applied.
- Both slides have green circles where N40rab seems to improve AIRS/CrIS agreement and red circles where N40rab degrades AIRS/CrIS agreement.

- The new N40rab AIRS L1B improves AIRS/CrIS agreement over most of the range.

- One area where N40rab degrades agreement is around 850 cm-1, at the end of AIRS module M-08.
  - This is an area where the AIRS instrument has been changing over its years in orbit, and some odd artifacts present at launch have nearly disappeared by the time of CrIS launch.
  - N40rab probably compensates for the at-launch AIRS instrument but introduces artifacts when applied to data from 2015.
  - The final v7 L1B calibration may need a time-dependence correction here.
  - The same may also be true in the shortwave band.

Original v5 uniform smoothed AIRS-CrIS



N40rab-adjusted uniform smoothed AIRS-CrIS